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ABSTRACT

This instructor's manual contains 13 units of instruction for a course on mechanical drafting with options for using computer-aided drafting (CAD). Each unit includes some or all of the following basic components of a unit of instruction: objective sheet, suggested activities for the teacher, assignment sheets and answers to assignment sheets, written test and answers to written test, unit evaluation form, teacher supplements, transparency masters, information sheet, student supplements, and job sheets. The teacher's edition also contains the following: supplementary materials on use of the publication; a competency profile; an instructional and task analysis; a list of related academic and workplace skills; and a list of tools, equipment, and materials needed. All the unit components focus on measurable and observable learning outcomes; units of instruction are designed for use in more than one lesson or class period of instruction. The instructional units in this course cover the following topics: introduction to mechanical drawing with CAD; tools and equipment; reference materials; dimensioning and tolerancing; fasteners and hardware; presentation drawings; materials and specifications; manufacturing processes; sheet metal developments; power transmission (chains, belts, and fluid power); power transmission (gears, bearings, and cams); layout and working drawings; and facility layout. Contains 54 references. (YC)

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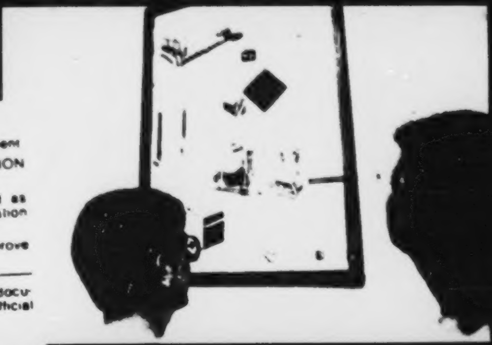
Mechanical Drafting with CAD



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Tolerancing and Dimensioning
Fasteners and Hardware
Presentation Drawings
Manufacturing Processes
Facility Layout
13 Profusely illustrated units
CAD alerts to pace students

Central Steel & Wire Company

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MAVCC

Teacher Edition

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Mechanical Drafting With CAD

Teacher Edition

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Foreword

Mechanical Drafting With CAD began as a revision of instructional materials from MAVCC's drafting series and quickly turned into a new book with significant changes and new instructional units. So what's new? The addition of *CAD* to the title is a dead giveaway because that's what these instructional materials are all about. Still, the problem of making a CAD book out of a book that should basically be dedicated to board drafting for beginners posed a minor challenge. Number one, when is a student ready to move on to CAD, and number two, what CAD software is the school drafting program using?

For students who do move through board assignments quickly and efficiently, CAD needs to be there to challenge them to move up. Since software is abundant, working with just one program could be limiting, especially for schools with limited funds or facilities. We hope *Mechanical Drafting With CAD* answers both the challenges with a device called a CAD Alert.

CAD Alert: These CAD Alerts will challenge the student to use a CAD workstation and point out how CAD can enhance the project. Both students and instructors will be continuously aware that good students merit the opportunity to move on to CAD, and assignments can be readily adapted to any CAD software.

In these instructional materials, there are many new references; some of them reflect important changes in standards. There are also supplementary materials for CAD that both instructors and students should know about. We hope their inclusion in these materials will help make it all the more effective in the classroom. Power transmission is treated in two separate units, and the text concludes with a new unit titled "Facilities Layout."

As you use *Mechanical Drafting With CAD*, we hope you will note your successes or problems with the text and let us know about either or both. Suggestions for improvements are welcome, and we do have a toll-free number, 1-800-654-3988. Or write to MAVCC, 1500 West Seventh Avenue, Stillwater, OK 74074-4364.

Sylvia Clark, Chairman
Board of Directors
Mid-America Vocational
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A special thank you goes to other publishers who have granted permission for some graphic materials that appear in the text; and to manufacturers whose catalogs and other reference materials have contributed significantly to almost every unit in this text.

To the Oklahoma Department of Vocational and Technical Education, a special thank you to the personnel in wordprocessing, art, and the print shop for helping develop and print a fine text.

Use of Introductory Materials

Introductory materials are included in the teacher guide only and contain useful information to assist administrators and teachers in planning for instruction.

In addition to the general information such as the table of contents, foreword, and acknowledgements page, information is included on the following:

1. **Use of this publication**—Explains the components of a unit of instruction and how they should be used as part of the teaching/learning process.

2. **Competency profile**—Provides a record of student performance for each task included in a unit of instruction. This becomes a part of the student's permanent records and should be utilized when directing the student toward employment opportunities.

3. **Instructional/task analysis**—Provides a quick review of contents of the publication; identifies cognitive (knowledge) skills and psychomotor (doing) skills addressed in each unit of instruction.

4. **Related academic and workplace skills list**—Classifies unit tasks (assignment sheets and job sheets) according to related academic and workplace skills being reinforced. Skill areas reflected by skill groups, sub skills, and descriptions have been identified using *Workplace Basics: The Skills Employers Want*, developed by the American Society for Training and Development (ASTD) and the U.S. Department of Labor and adapted by MAVCC.

5. **Tools, equipment, and materials list**—Provides a comprehensive list of those items needed to successfully complete the assignment sheets and/or job sheets; assists administrator/teacher in determining program costs.

6. **Reference list**—Provides a comprehensive list of resources used in the development of this publication.

A glossary of terms may also be provided in the introductory materials depending on subject matter and committee recommendations.

As you use these materials, it is hoped that they will provide useful information to meet a variety of needs.

Use of This Publication

Instructional units

Mechanical Drafting With CAD contains 13 units of instruction. Each instructional unit in a teacher guide includes some or all of the following basic components of a unit of instruction: objective sheet. suggested activities for the teacher. answers to assignment sheets. answers to written test. written test. unit evaluation form. teacher supplements. transparency masters. information sheet. assignment sheets. student supplements. and job sheets.

All of the unit components focus on measurable and observable learning outcomes. Teachers are encouraged to supplement. personalize. localize. and motivate with these materials in order to develop a complete teaching/learning process.

Units of instruction are designed for use in more than one lesson or class period of instruction. Careful study of each unit of instruction by the teacher will help to determine the following:

- Amount of materials that can be covered in each class period.
- Skills that must be demonstrated.
- Amount of class time needed for demonstrations.
- Amount of time needed for student practice.
- Supplementary materials. including print and nonprint media and equipment and supplies. that must be ordered.
- Resource people who must be contacted.

Objective sheet (Color code: White)

Each unit of instruction is based on performance objectives which state the goals for successful completion of the course. These performance objectives are stated in two forms: unit objectives which state the expected performance of each student after completion of the unit of instruction. and specific objectives which state what the student must do to reach the unit objective.

The objectives should be provided for students and stressed throughout the teaching/learning process. This will help answer any questions concerning performance requirements for each instructional unit. The objectives can also help determine teaching strategies and instructional methods. Teachers should prepare for each unit by deciding how each objective can best be taught.

Teachers should feel free to modify. delete. or add objectives in order to meet the needs of the students and community. When objectives are added. the teacher should remember to supply the needed information. assignment and/or job sheets. and criterion test items.

Suggested activities (Color code: Pink)

This component is included only in the teacher guide. The suggested activities assist teachers during the preparation stage of the teaching learning process by providing an instructional plan, teaching suggestions, and a list of supplemental resources. Ways to integrate academic and workplace skills have been included in the teacher suggestions, and skill areas have been noted in bold. (A table of academic and workplace skills with accompanying definitions has been provided on page xv.) The teacher should read the suggested activities before teaching the units and decide how each objective can best be taught. Time should also be allowed to obtain supplemental materials, prepare audiovisual materials, and contact outside resources. Duties of the teacher will vary according to the particular unit.

References used in the development of each unit are listed in the suggested-activities section, along with suggested supplemental resources that may be used to teach the unit. These materials can be used by the teacher to supplement her or his knowledge of the subject area or to help students with particular interests or objectives in the area covered.

Instructions for evaluating student performance on the job sheets are also included in the suggested-activities section. Teachers should select and discuss with students the rating scale that will be used.

Assignment and written test answers (Color code: Pink)

Assignment-sheet answers and written-test answers are designed to assist the teacher in evaluation of student performances.

Written test (Color code: Yellow)

This component provides criterion-referenced evaluation of every cognitive objective listed in the unit of instruction. The test appears in the teacher guide only, but duplication is permitted for student use. If objectives have been added, deleted, or modified, appropriate changes should be made on the written test. It is recommended that the tests be divided into shorter tests covering three or four objectives at a time and given soon after those objectives have been covered. A selection of test items from the units covered may be used for final tests at the end of each term if desired.

Unit evaluation form (Color code: White)

This sheet provides teachers with a record of each students performance on a unit of instruction. It includes space for assignment sheet ratings, job sheet ratings, written test scores, and teacher comments. The unit evaluation form is included in the teacher guide only, but may be duplicated.

Use of This Publication

Teacher supplements (Color code: White)

This component is included only in the teacher guide. Teacher supplements are optional materials for the teacher to use. They have three purposes: to provide the teacher with higher level materials to stretch the advanced student, with remedial information or practice to assist the less-advanced student, and with state-of-the-art information in which the teacher may not have background or with information that is not readily available in other books. Some teacher supplements may be duplicated for student use and are marked accordingly.

Transparency masters (Color code: White)

Transparencies are included in the teacher guide only and are used to direct the students' attention to the topic of discussion. They may provide illustrations, charts, schematics, or additional information needed to clarify and reinforce objectives included in the unit of instruction.

Information sheet (Color code: Green)

The information sheet provides the content essential for meeting the cognitive (knowledge) objectives of the unit. Teachers will find that the information sheet serves as an excellent guide for presenting background knowledge necessary to develop the skills specified in the unit objective. Students should read the information sheet before the information is discussed in class. Space is provided in margins for students and teachers to add notes that supplement, localize, personalize, or provide information for the teaching of each objective.

Student supplements (Color code: White)

Student supplements are included in the student manual. The information presented in a student supplement may consist of tables, charts, written information, forms, or other information students will need in order to complete one or more of the assignment and/or job sheets. Students are not directly tested over the information presented in a supplement; however, their ability to apply this information may be evaluated in the completion of assignment sheets or job sheets.

Assignment sheets (Color code: Tan)

Assignment sheets provide students with pencil and paper activities that give students the opportunity to make practical application of the knowledge in the information sheet. Criteria are provided to objectively evaluate student performance.

Job sheets (Color code: Blue)

The job sheets provide criteria to objectively evaluate student performance, a list of required equipment and materials, and a step-by-step procedure for performing a psychomotor skill. The teacher should discuss the equipment and materials available in the classroom and/or laboratory and demonstrate the procedure prior to having students practice procedure. When a student is ready to be evaluated, the teacher should follow instructions for evaluating student performance which may be found in the teacher guide.

Job sheets are an important segment of each unit. Job sheets provide potential employers with a picture of the skills being taught during training and the performances that might reasonably be expected from an individual who has had this training.

Disseminating material

Material may be given out a unit or page at a time to keep the material before the student always new. Some teachers ask students to furnish a three-ring binder or folder for the current unit of study. This is convenient for students taking the material home to study. Upon completion, each unit is then placed in a larger binder. Some teachers prefer to store the material by unit in filing cabinets or boxes until needed.

For best results, provide student materials for each student. Student manuals contain objective sheets, information sheets, student supplements, assignment sheets, and job sheets. Students should be allowed to take their materials home at the end of the course.

Academic and Workplace Skills
(Classifications and Definitions)

Skill Groups	Sub Skills	Definitions
Learning Skills	Learning to learn	Developing ability to apply knowledge to other situations; knowing how to learn.
Foundation Skills	Reading	Comprehending written information and analyzing, summarizing, and applying what has been read to a specific task.
	Writing	Communicating a thought, idea or fact in written form in a clear, concise manner.
	Math	Applying computation skills such as reasoning, estimation, and problem solving as they are actually used on the job.
	Science	Applying knowledge learned through study or practice that is based on scientific principles as they relate to specific tasks.
Communication Skills	Listening	Listening for content, conversation, long-term contexts, emotional meaning, and directions.
	Oral communication	Communicating a thought, idea, or fact in spoken form in a clear, concise manner.
Adaptability Skills	Creative thinking	Using imagination to create something new—i.e an idea, invention, work of art.
	Problem solving (critical thinking)	Recognizing and defining problems, inventing, and implementing solutions, and tracking and evaluating results.
Personal Management Skills	Self-esteem	Developing self-confidence and creating a positive self-image.
	Motivation goal setting	Setting and meeting defined goals and objectives.
	Personal and career development	Emphasizing self-direction by establishing and implementing a plan.
Group Effectiveness Skills	Interpersonal relations	Developing ability to maintain positive relations with others.
	Negotiation	Resolving conflict between two or more individuals.
	Teamwork	Working together in a group to reach a common goal.
Influence Skills	Organizational effectiveness	Adapting to the organization's goals, values, culture, and traditional modes of operation.
	Leadership	Directing/influencing group in performance of a specific task; accepting responsibility for others.

Mechanical Drafting With CAD

Competency Profile

Name: ______________________________

Directions: Evaluate the student using the rating scale below. Write the appropriate number to indicate the degree of competency achieved. The descriptions associated with each of the numbers focused on a level of student performance for each of the tasks listed. The written test scoreline is provided for optional teacher use. It may not be applicable in all cases.

Option A

Rating scale
4 - Skilled - Can perform job with no additional training
3 - Moderately Skilled - Has performed job during training program; limited additional training may be required
2 - Limited Skill - Has performed job during training program; additional training is required to develop skill
1 - Unskilled - Is familiar with process, but is unable to perform job
0 - No Exposure - No information or practice provided during training program, complete training required
NA - Non-applicable

Option B

Yes - Can perform with no additional training
No - Is unable to perform satisfactorily

Unit 1: Introduction to Mechanical Drafting With CAD

______1. Evaluate a mechanical drawing.
______2. Evaluate services from a professional organization.
______3. ______________________________

______Written Test Score

Unit 2: Tools and Equipment

______1. Read micrometer settings in inches and millimeters.
______2. Read vernier calipers in inches and millimeters.
______3. Measure with engineer, machinist, and metric scales.
______4. Compute mechanical drafting problems with a hand-held calculator.
______5. Measure with a micrometer.
______6. Measure with a vernier caliper.
______7. ______________________________

______Written Test Score

Unit 3: Reference Materials

______1. Determine manufacturer and mechanical components from the *Thomas Register*.
______2. Request product literature in a letter.
______3. Write a brief, technical report using reference materials.
______4. ____

______Written Test Score

Unit 4: Dimensioning and Tolerancing

______1. Dimension an object completely.
______2. Calculate and dimension clearance fit tolerances using standard fit tables.
______3. Calculate and dimension interference fit tolerances using standard fit tables.
______4. Calculate and assign tolerances to mating parts using standard fit tables.
______5. Calculate and dimension hole-size limits for standard dowels.
______6. Dimension an object using position and form tolerances.
______7. Determine ranges of motion of limbs and spaces required for a person.
______8. ____

______Written Test Score

Unit 5: Fasteners and Hardware

______1. Construct thread symbols.
______2. Construct symbols of bolts, screws, and nuts.
______3. Construct an assembly using various fasteners.
______4. Construct a weldment assembly drawing.
______5. Construct spring drawings to include specifications.
______6. Construct keys in assembled drawings.
______7. Write specifications for hardware from vendor catalogs.
______8. ____

______Written Test Score

Unit 6: Presentation Drawings

______1. Shade pictorials.
______2. Construct conceptual presentation sketches.
______3. Construct design sketches.
______4. Construct a dimetric presentation drawing.
______5. Construct an oblique presentation drawing.
______6. Construct a two-point presentation drawing.
______7. Construct an exploded assembly presentation drawing.
______8. ____

______Written Test Score

Unit 7 Materials and Specifications

______1. Determine wire and sheet metal size from gage number.
______2. Select materials from a materials stock book.
______3. ____________________

______Written Test Score

Unit 8: Manufacturing Processes

______1. Calculate bend allowance for sheet metal.
______2. Design a casting part.
______3. Design a forging part.
______4. Design a welded part.
______5. Design a thermoplastic part.
______6. ____________________

______Written Test Score

Unit 9: Sheet Metal Developments

______1. Label points, lines, and planes in views.
______2. Identify true lengths and types of lines.
______3. Identify true lengths and types of planes.
______4. Construct true length lines and true length planes using auxiliary views.
______5. Construct true length of lines by rotation.
______6. Construct true sizes of planes by rotation.
______7. Locate elements of single curved surfaces.
______8. Construct intersections of surfaces.
______9. Construct intersections using the two-view method.
______10. Construct radial line developments.
______11. Construct parallel line developments.
______12. Construct special developments using triangulation.
______13. ____________________.

______Written Test Score

Unit 10: Power Transmission: Chains, Belts, and Fluid Power

______1. Select a chain drive.
______2. Select V-belts for given applications.
______3. ____________________

______Written Test Score

Unit 11: Power Transmission: Gears, Bearing, and Cams

______1. Construct a spur gear drawing.
______2. Construct a bevel gear drawing.
______3. Construct a worm and worm gear.
______4. Calculate gear ratios.

_____5. Determine gear rotation.
_____6. Calculate gear speeds.
_____7. Construct a cam drawing.
_____8. Select types of bearings from handbooks.
_____9. ______________________________

_____Written Test Score

Unit 12: Layouts and Working Drawings

_____1. Draw a design layout.
_____2. Draw a set of detail drawings.
_____3 Draw an assembly drawing.
_____4. Complete a detailed title block and revision block.
_____5. Complete a parts list.
_____6. Make a drawing revision.
_____7. ______________________________

_____Written Test Score

Unit 13: Facility Layout

_____1. Develop a flow process chart.
_____2. Develop a relationship matrix.
_____3. Create a bubble diagram.
_____4. Create a block diagram.
_____5 Create a facility layout.
_____6. ______________________________

_____Written Test Score

COMMENTS: ______________________________

____

____

____

____

Evaluator: ______________________ Date: ______________

* **Permission to duplicate this profile is granted.**

Mechanical Drafting With CAD

Instructional/Task Analysis

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 1: Introduction to Mechanical Drafting With CAD

1. Terms and definitions.
2. CAD drafting jobs and their descriptions.
3. Industries that employ mechanical CAD drafters.
4. Guidelines for planning a mechanical CAD drafting career.
5. Guidelines for becoming a good CAD operator.
6. CAD skill levels and their workplace applications.
7. Qualifications employers look for in a mechanical CAD drafter.
8. Career outlooks for mechanical CAD drafters.
9. Career options for mechanical CAD drafters.
10. Professional organizations and their benefits to CAD students.
11. Evaluate a mechanical drawing. (Assignment Sheet 1)
12. Evaluate services from a professional organization. (Assignment Sheet 2)

Unit 2: Tools and Equipment

1. Terms and definitions.
2. Templates and their use in mechanical drafting.
3. Precision measuring instruments and their uses.
4. Welding measuring instruments that drafters need to know.

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 2: Tools and Equipment (Con't.)

5. Basic scales used in mechanical drafting.
6. Metric scales and their use in mechanical drafting.
7. Hand-held calculators and their uses in mechanical drafting.

8. Read micrometer settings in inches and millimeters. (Assignment Sheet 1)
9. Read vernier calipers in inches and millimeters. (Assignment Sheet 2)
10. Measure with engineer, machinist, and metric scales. (Assignment Sheet 3)
11. Compute mechanical drafting problems with a hand-held calculator. (Assignment Sheet 4)
12. Measure with a micrometer. (Job Sheet 1)
13. Measure with a vernier caliper. (Job Sheet 2)

Unit 3: Reference Materials

1. Terms and definitions.
2. Manufacturing catalogs that contain product information.
3. Mechanical drafting standards organizations.
4. Mechanical drafter and designer handbooks.
5. Standards found in an ANSI drafting manual.
6. Types of standard parts specified by ANSI.
7. ANSI dimensioning and surface finish standards.
8. ANSI small tools and machine elements standards.

Related Information: What the Student Should Know	**Application: What the Student Should Be Able to Do**

Unit 3: Reference Materials (Con't.)

9. ANSI metric fastener standards.

10. DOD military standards.

11. Determine manufacturer and mechanical components from the *Thomas Register*. (Assignment Sheet 1)

12. Request product literature in a letter. (Assignment Sheet 2)

13. Write a brief, technical report using reference materials. (Assignment Sheet 3)

Unit 4: Dimensioning and Tolerancing

1. Terms and definitions.

2. Size dimensions for given geometric shapes.

3. Location dimensions for geometric shapes.

4. Mating dimensions in an assembly drawing.

5. Basic guidelines for numerical control dimensioning.

6. Fits for inch units and their applications.

7. Fits for metric units and their applications.

8. Limits for clearance fit in inch units using the basic hole system.

9. Limits for locational fit in inch units using the basic hole system.

10. Limits for force fit in inch units using the basic hole system.

11. Limits for clearance fit in inch units using the basic shaft size system.

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 4: Dimensioning and Tolerancing (Con't.)

12. Limits for clearance fit in metric units using the basic hole system.
13. Limits for transition fit in metric units using the basic hole system.
14. Limits for interference fit in metric units using the basic hole system.
15. Tolerance ranges and their relationship to costs and shop processes.
16. Guidelines for determining clearance fit on standard dowels.
17. Guidelines for determining interference fit on standard dowels.
18. Guidelines for determining limit dimensions for the interchangability of parts.
19. Steps for determining limit dimensions for intermediate parts to retain overall limits.
20. ANSI and ISO symbols for tolerances of position and form.
21. ANSI modifying symbols for tolerances of position and form and their terms.
22. Position and form symbols in a drawing.
23. Descriptions of position and form.
24. Positional tolerancing.
25. Features of MMC and RFS.
26. Angular tolerances.

Unit 4: Dimensioning and Tolerancing (Con't.)

Related Information: What the Student Should Know

27. Correct and incorrect placement of surface quality symbols.
28. Surface quality notes.
29. Lay symbols with their meanings.
30. Production processes and the degrees of roughness they produce.
31. Recommended values for surface quality roughness.
32. Advantages of using CAD for dimensioning and tolerancing.

Application: What the Student Should Be Able to Do

33. Dimension an object completely. (Assignment Sheet 1)
34. Calculate and dimension clearance fit tolerances using standard fit tables. (Assignment Sheet 2)
35. Calculate and dimension interference fit tolerances using standard fit tables. (Assignment Sheet 3)
36. Calculate and assign tolerances to mating parts using standard fit tables. (Assignment Sheet 4)
37. Calculate and dimension hole-size limits for standard dowels. (Assignment Sheet 5)
38. Dimension an object using position and form tolerances. (Assignment Sheet 6)
39. Determine ranges of motion of limbs and spaces required for a person. (Assignment Sheet 7)

Unit 5: Fasteners and Hardware

1. Terms and definitions.
2. Thread nomenclatures and their meanings.
3. Other fasteners and their applications.
4. Screw heads and their uses.
5. Screw thread nomenclature.
6. Screw thread profiles.
7. Thread leads.

Unit 5: Fasteners and Hardware (Con't.)

Related Information: What the Student Should Know	**Application: What the Student Should Be Able to Do**
8. Ways of presenting screw threads.	
9. Fit for unified and metric threads and their applications.	
10. Thread notes for American National screw threads.	
11. Thread notes for American National Standard Unified screw threads.	
12. Thread notes for metric screw threads.	
13. Ways to present pipe threads.	
14. Types of threaded removable fasteners.	
15. Types of locknuts and locking devices.	
16. Types of standard cap screws.	
17. Types of machine screws.	
18. Types of heads and points on set screws.	
19. Miscellaneous bolts, nuts, and screws.	
20. Standard large and small rivets.	
21. Conventional rivet symbols and their meanings.	
22. Advantages of plastic fasteners over metal fasteners.	
23. Shaft locking hardware.	
24. Types of springs and their characteristics.	

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 5: Fasteners and Hardware (Con't.)

25. Types of springs from their notes and dimensions.

26. Types of spring clips with their designs.

27. Types of keys designed to prevent relative motion between wheel and shaft.

28. Types of machine pins.

29. Types of washers and their applications.

30. Types of tooth lock washers.

31. Insert characteristics and their industrial applications.

32. Industrial applications of spring washer designs.

33. Quick opening and quick locking devices.

34. Miscellaneous machine elements with their uses.

35. Advantages of welding instead of using threaded fasteners.

36. Types of welded joints.

37. Parts of a welding symbol.

38. Basic arc and gas welding symbols.

39. Supplementary welding symbols.

40. Guidelines for dimensioning welds to determine the dimensions of a fillet weld.

41. Resistance welding symbols.

Unit 5: Fasteners and Hardware (Con't.)

Related Information: What the Student Should Know

42. Considerations for using adhesives for bonding materials.

43. Considerations for joint design when using adhesive bonding.

44. Joint designs for adhesive bonding.

45. CAD symbol libraries and their uses.

Application: What the Student Should Be Able to Do

46. Construct thread symbols. (Assignment Sheet 1)

47. Construct symbols of bolts, screws, and nuts. (Assignment Sheet 2)

48. Construct an assembly containing various fasteners. (Assignment Sheet 3)

49. Construct a weldment assembly drawing. (Assignment Sheet 4)

50. Construct spring drawings to include specifications. (Assignment Sheet 5)

51. Construct keys in assembled positions. (Assignment Sheet 6)

52. Write specifications for hardware from vendor catalogs. (Assignment Sheet 7)

Unit 6: Presentation Drawings

1. Terms and definitions.

2. Types of presentation sketches and drawings and their purposes.

3. Steps in sketching.

4. Guidelines for ellipse construction.

5. Places where presentation drawings are used.

6. Techniques for shading presentation drawings.

7. Types of axonometric drawings and their characteristics.

8. Types of oblique drawings and their characteristics.

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 6: Presentation Drawings (Con't.)

9. Parts of an exploded assembly drawing and their uses.
10. CAD applications for presentation drawings.
11. Special requirements for patent drawings.

12. Shade pictorials. (Assignment Sheet 1)
13. Construct conceptual presentation sketches. (Assignment Sheet 2)
14. Construct design sketches. (Assignment Sheet 3)
15. Construct a diametric presentation drawing. (Assignment Sheet 4)
16. Construct an oblique presentation drawing. (Assignment Sheet 5)
17. Construct a two-point presentation drawing. (Assignment Sheet 6)
18. Construct an exploded assembly presentation drawing. (Assignment Sheet 7)

Unit 7: Materials and Specifications

1. Terms and definitions.
2. Professional organizations and their abbreviations and their activities.
3. Specifications used on mechanical drawings.
4. Basic metal heat treatments and their characteristics.
5. Surface hardening treatments and their characteristics.
6. Statements about forms of carbon steel.
7. Categories of pipe usage.
8. Specifications for tubing callouts.

Related Information: What the Student Should Know

Unit 7: Materials and Specifications (Con't.)

9. Structural steel shapes and their specifications.
10. Standard mill sizes.
11. Metal properties and their definitions.
12. Guidelines for selecting materials.
13. Metal characteristics and types.
14. Types of ferrous manufacturing metals.
15. Parts of the steel numbering system.
16. Basic copper-type metals.
17. Conditions of aluminum and their designations.
18. Original aluminum alloys and their modifiers.
19. Advantages and disadvantages of aluminum.
20. Advantages and disadvantages of zinc.
21. Types of plastics and their characteristics.
22. Advantages and disadvantages of plastics.
23. Refractories and their applications.

Application: What the Student Should Be Able to Do

24. Determine Wire and sheet metal size from gage numbers. (Assignment Sheet 1)
25. Select materials from a materials stock book. (Assignment Sheet 2)

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 8: Manufacturing Processes

1. Terms and definitions.
2. Metal treatment processes and their characteristics.
3. Production processes and their characteristics.
4. Principal types of drawings for manufacturing processes.
5. Casting terms and their definitions.
6. Guidelines for designing a casting.
7. Forging terms and their definitions.
8. Guidelines for designing a forging.
9. Welding terms and their definitions.
10. Pattern and machine dimensions and their applications.
11. Guidelines for designing a welded assembly.
12. Types of machines with their uses.
13. Advantages of numerical control machinery.
14. Plastic manufacturing terms and their definitions.
15. Types of plastics and the methods for their fabrication.
16. Guidelines for designing plastic products.
17. Sheet metal processing terms and their definitions.
18. Sheet metal hems and joints.
19. Bend allowance.
20. Calculate bend allowance for sheet metal. (Assignment Sheet 1)
21. Design a casting part. (Assignment Sheet 2)
22. Design a forging part. (Assignment Sheet 3)
23. Design a welded part. (Assignment Sheet 4)
24. Design a thermoplastic part. (Assignment Sheet 5)

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 9: Sheet Metal Developments

Related Information: What the Student Should Know

1. Terms and definitions.
2. Surface conditions and their characteristics.
3. Guidelines for visualization of near points and planes.
4. Guidelines for visualization of far points and planes.
5. Guidelines for observing planes.
6. Guidelines for labeling points, lines, and planes.
7. Steps for constructing an auxiliary view.
8. True length lines and true size planes.
9. Point views of lines and edge views of planes.
10. Rotation characteristics.
11. Elements of single curved surfaces.
12. Methods for finding intersections of surfaces.
13. General groups of sheet metal developments and their characteristics.
14. Bend allowance.

Application: What the Student Should Be Able to Do

15. Label points, lines, and planes in views. (Assignment Sheet 1)
16. Identify true lengths and types of lines. (Assignment Sheet 2)
17. Identify true sizes and types of planes. (Assignment Sheet 3)
18. Construct true length lines and true length planes using auxiliary views. (Assignment Sheet 4)
19. Construct true length of lines by rotation. (Assignment Sheet 5)
20. Construct true sizes of planes by rotation. (Assignment Sheet 6)
21. Locate elements of single curved surfaces. (Assignment Sheet 7)
22. Construct intersections of surfaces. (Assignment Sheet 8)
23. Construct intersections of surfaces using the two-view method. (Assignment Sheet 9)
24. Construct radial line developments. (Assignment Sheet 10)
25. Construct parallel line developments. (Assignment Sheet 11)
26. Construct special developments using triangulation. (Assignment Sheet 12)

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 10: Power Transmission: Chains, Belts, and Fluid Power

1. Terms and definitions.
2. Chain drives and their advantages over gear drives.
3. Gear drives and their advantages over chain drives.
4. Chain drives and their advantages over belt drives..
5. Major types of power transmission chains.
6. Belt drives and their advantages over chain drives.
7. Guidelines for selecting a V-belt drive.
8. Basic hydraulic components and their functions.
9. Basic pneumatic components and their functions.
10. Air circuit components.
11. Select a chain drive. (Assignment Sheet 1)
12. Select V-belts for given applications. (Assignment Sheet 2)

Unit 11: Power Transmission: Gears, Bearings, and Cams

1. Terms and definitions.
2. Types of gears and their relation of axes positions.
3. Parts of gear teeth.
4. Parts of pinion and gear.
5. Cutting data needed for spur gear drawings.
6. Parts of a bevel gear.
7. Cutting data needed for bevel gears.

Unit 11: Power Transmission: Gears, Bearings, and Cams (Con't.)

Related Information: What the Student Should Know

8. Cutting data needed for worm.
9. Cutting data needed for worm wheel gear.
10. Gear ratios.
11. Gear rotation.
12. Gear speed.
13. Types of couplings.
14. Types of bearings.
15. Cam nomenclature.
16. Types of cam followers.
17. Types of cam motions.

Application: What the Student Should Be Able to Do

18. Construct a spur gear drawing. (Assignment Sheet 1)
19. Construct a bevel gear. (Assignment Sheet 2)
20. construct a worm and worm gear. (Assignment Sheet 3)
21. Calculate gear ratios. (Assignment Sheet 4)
22. Determine gear rotation. (Assignment Sheet 5)
23. Calculate gear speeds. (Assignment Sheet 6)
24. Construct a cam drawing. (Assignment Sheet 7)
25. Select types of bearings from handbooks. (Assignment Sheet 8)

Unit 12: Layouts and Working Drawings

1. Terms and definitions.
2. Standard and additional information on a title form.
3. Information on a revision block.
4. Information on a bill of materials/parts list.
5. Stages in the design process.
6. Design layouts and their characteristics.
7. Basic elements of a design layout sketch.
8. Parts of a detail drawing and their functions.

Related Information: What the Student Should Know

Application: What the Student Should Be Able to Do

Unit 12: Layouts and Working Drawings (Con't.)

9. Parts of an assembly drawing and their functions.
10. Information on outline or installation assembly drawings.
11. Information on weldment assembly drawings.
12. Parts of forging drawings and their characteristics.
13. Parts of a pattern or casting drawing and their characteristics.

14. Draw a design layout. (Assignment Sheet 1)
15. Draw a set of detail drawings. (Assignment Sheet 2)
16. Draw an assembly drawing. (Assignment Sheet 3)
17. Complete a detailed title block and revision block. (Assignment Sheet 4)
18. Complete a parts list. (Assignment Sheet 5)
19. Make a drawing revision. (Assignment Sheet 6)

Unit 13: Facility Layout

1. Terms and definitions.
2. Situations where facility layouts are needed.
3. Advantages of reorganizing a facility layout.
4. Contents of a flow process chart and their symbols.
5. Types of facilities layouts used in production processes.
6. Characteristics of a process layout.
7. Characteristics of a product layout.
8. Characteristics of a fixed-position layout.
9. Characteristics of a group layout.
10. Stages in building a facility layout and their characteristics.

11. Develop a flow process chart. (Assignment Sheet 1)
12. Develop a relationship matrix. (Assignment Sheet 2)
13. Create a bubble diagram. (Assignment Sheet 3)
14. Create a block diagram. (Assignment Sheet 4)
15. Create a facility layout. (Assignment Sheet 5)

Related Academic and Workplace Skills For *Mechanical Drafting With CAD*

Task	Skill Group	Sub Skill	Description
Unit 1: Introduction to Mechanical Drafting With CAD			
Evaluate a mechanical drawing (A.S. 1)	Foundation Skills	Reading	Comprehends written information and applies it to a task
		Science	Applies technology training to a problem
Evaluate services from a professional organization (A.S.2)	Foundation Skills	Reading and Writing	Reads References and writes for information
Unit 2: Tools and Equipment			
Read micrometer settings in inches and millimeters (A.S. 1)	Foundation Skills	Math	Uses a measuring tool to solve a problem
Read vernier calipers in inches and millimeters (A.S. 2)	Foundation Skills	Math	Uses a measuring tool to solve a problem
Measure with engineer, machinist, and metric scales (A.S. 3)	Foundation Skills	Math	Uses a measuring tool to solve a problem
Compute mechanical drafting problems with a hand-held calculator (A.S. 4)	Foundation Skills	Math	Uses a digital device to solve a problem
Measure with a micrometer (J.S. 1)	Foundation Skills	Math	Uses a measuring tool to solve a problem
Measure with a vernier caliper (J.S. 2)	Foundation Skills	Math	Uses a measuring tool to solve a problem
Unit 3: Reference Materials			
Determine manufacturer and mechanical components from the *Thomas Register* (A.S. 1)	Foundation Skills	Reading	Reads references to find needed information
Request product literature in a letter (A.S. 2)	Foundation Skills	Reading and Writing	Reads references and writes for selected materials
Write a brief, technical report using reference materials (A.S. 3)	Foundation Skills	Reading and Writing	Reads and reports technical information from a reference
Unit 4: Dimensioning and Tolerancing			
Dimension an object completely (A.S. 1)	Foundation Skills	Math	Applies critical lines and measurements to a drawing
Calculate and dimension clearance fit tolerances using standard fit tables (A.S. 2)	Foundation Skills	Reading	Comprehends and applies technical information from a table

Task	Skill Group	Sub Skill	Description
Unit 4: Dimensioning and Tolerancing (Con't.)			
Calculate and dimension interference fit tolerances using standard fit tables (A.S. 3)	Foundation Skills	Reading	Comprehends and applies technical information from a table
Calculate and assign tolerances to mating parts using standard fit tables (A.S. 4)	Foundation Skills	Reading	Comprehends and applies technical information from a table
Calculate and dimension hole-size limits for standard dowels (A.S. 5)	Foundation Skills	Math	Applies critical lines and measurements to a drawing
Dimension and object using position and form tolerances (A.S. 6)	Foundation Skills	Math	Applies critical lines and measurements to a drawing
Determine ranges of motion of limbs and spaces required for a person (A.S. 7)	Foundation Skills	Reading	Interprets drawings to solve design problems
Unit 5: Fasteners and Hardware			
Construct thread symbols (A.S. 1)	Foundation Skills	Math	Applies critical lines and measurements to a drawing
Construct symbols of bolts, screws, and nuts (A.S. 2)	Foundation Skills	Math	Applies critical lines and measurements to a drawing
Construct an assembly containing various fasteners (A.S. 3)	Foundation Skills	Math	Applies critical lines and measurements to a drawing
Construct a weldment assembly drawing (A.S. 4)	Foundation Skills	Math	Applies critical lines and measurements to a drawing
Construct spring drawings to include specifications (A.S. 5)	Foundation Skills	Math	Applies critical lines and measurements to a drawing
Construct keys in assembled drawings (A.S. 6)	Foundation Skills	Math	Applies critical lines and measurements to a drawing
Write specifications for hardware from vendor catalogs (A.S. 7)	Foundation Skills	Reading and Writing	Comprehends written specifications and writes information to verify location
Unit 6. Presentation Drawings			
Shade pictorials (A.S. 1)	Adaptability Skills	Creative Thinking	Applies personal style to a drawing task
Construct conceptual presentation sketches (A.S. 2)	Adaptability Skills	Creative Thinking	Applies personal style to a drawing task
Construct design sketches (A.S. 3)	Adaptability Skills	Creative Thinking	Applies personal style to a drawing task
Construct a diametric presentation drawing (A.S. 4)	Foundation Skills	Math	Applies critical lines and measurements to a drawing

Task	Skill Group	Sub Skill	Description
Unit 6: Presentation Drawings			
Construct an oblique presentation drawing (A.S. 5)	Foundation Skills	Math	Applies critical lines and measurements to a drawing
Construct a two-point presentation drawing (A.S. 6)	Foundation Skills	Math	Applies critical lines and measurements to a drawing
Construct an exploded assembly presentation drawing (A.S. 7)	Foundation Skills	Math	Applies critical lines and measurements to a drawing
Unit 7: Materials and Specifications			
Determine wire and sheet metal size from gage numbers (A.S. 1)	Foundation Skills	Reading	Comprehends technical information from a table
Select materials from a materials stock book (A.S. 2)	Foundation Skills	Reading	Selects technical items from a parts reference book
Unit 8: Manufacturing Processes			
Calculate bend allowance for sheet metal (A.S. 1)	Foundation Skills	Math	Applies a mathematical formula to solve a problem
Design a casting part (A.S. 2)	Foundation Skills	Math and Science	Applies critical lines and measurements to complete a scientific process
Design a forging part (A.S. 3)	Foundation Skills	Math and Science	Applies critical lines and measurements to complete a scientific process
Design a welded part (A.S. 4)	Foundation Skills	Math and Science	Applies critical lines and measurements to complete a scientific process
Design a thermoplastic part (A.S. 5)	Foundation Skills	Math and Science	Applies critical lines and measurements to complete a scientific process
Unit 9: Sheet Metal Developments			
Label points, lines, and planes in views (A.S. 1)	Foundation Skills	Math	Applies mathematical principles to interpret drawings
Identify true lengths and types of lines (A.S. 2)	Foundation Skills	Math	Applies mathematical principles to identify lines in a drawing
Identify true sizes and types of planes (A.S. 3)	Foundation Skills	Math	Applies mathematical principles to identify planes in a drawing
Construct true length lines and true length planes using auxiliary views (A.S. 4)	Foundation Skills	Math	Applies mathematical principles to complete a drawing
Construct true length of lines by rotation (A.S. 5)	Foundation Skills	Math	Applies mathematical principles to complete a drawing

Task	Skill Group	Sub Skill	Description
Unit 9. Sheet Metal Developments (Con't.)			
Construct true sizes of planes by rotation (A.S. 6)	Foundation Skills	Math	Applies mathematical principles to complete a drawing
Locate elements of single curved surfaces (A.S. 7)	Foundation Skills	Math	Applies mathematical principles to locate elements in a drawing
Construct intersections of surfaces (A.S. 8)	Foundation Skills	Math	Applies mathematical principles to complete a drawing
Construct intersections of surfaces using the two-view method (A.S. 9)	Foundation Skills	Math	Applies mathematical principles to complete a drawing
Construct radial line developments (A.S. 10)	Foundation Skills	Math	Applies mathematical principles to complete a drawing
Construct parallel line developments (A.S. 11)	Foundation Skills	Math	Applies mathematical principles to complete a drawing
Construct special developments using triangulation (A.S. 12)	Foundation Skills	Math	Applies mathematical principles to complete a complex drawing
Unit 10: Power Transmission: Chains, Belts, and Fluid Power			
Select a chain drive (A.S. 1)	Foundation Skills	Reading	Comprehends and uses technical information from a catalog
Select V-belts for given applications (A.S. 2)	Foundation Skills	Reading	Comprehends and uses technical information from a catalog
Unit 11: Power Transmission: Gears, Bearings, and Cams			
Construct a spur gear drawing (A.S. 1)	Foundation Skills	Math	Applies mathematical principles to complete a drawing
Construct a bevel gear drawing (A.S. 2)	Foundation Skills	Math	Applies mathematical principles to complete a drawing
Construct a worm and worm gear (A.S. 3)	Foundation Skills	Math	Applies mathematical principles to complete a drawing
Calculate gear ratios (A.S. 4)	Foundation Skills	Science	Applies a scientific principle to solve a problem
Determine gear rotation (A.S. 5)	Foundation Skills	Science	Applies a scientific principle to solve a problem
Construction gear speeds (A.S. 6)	Foundation Skills	Math	Applies mathematical formula to solve a workplace problem
Construct a cam drawing (A.S. 7)	Foundation Skills	Math	Applies a mathematical principle to complete a drawing
Select types of bearings from handbooks (A.S. 8)	Foundation Skills	Reading	Comprehends and uses materials from manufacturers' handbooks

Task	Skill Group	Sub Skill	Description
Unit 12: Layouts and Working Drawings			
Draw a design layout (A.S. 1)	Foundation Skills	Math	Applies mathematical principles to complete a drawing
Draw a set of detail drawings (A.S. 2)	Foundation Skills	Math and Science	Applies math and science skills to complete a drawing
Draw an assembly drawing (A.S. 3)	Foundation Skills	Math and Science	Applies math and science skills to complete a drawing
Complete a detailed title block and revision block (A.S. 4)	Foundation Skills	Writing	Fills in technical information on a form
Complete a parts list (A.S. 5)	Foundation Skills	Writing	Fills in technical information on a form
Make a drawing revision (A.S. 6)	Foundation Skills	Math and Science	Applies math and science skills to correct a problem
Unit 13: Facility Layout			
Develop a flow process chart (A.S. 1)	Foundation Skills	Science	Applies scientific procedures to solve a problem
Develop a relationship matrix (A.S. 2)	Foundation Skills	Science	Applies scientific procedures to solve a problem
Create a bubble diagram (A.S. 3	Foundation Skills	Math and Science	Applies mathematical and scientific procedures to solve a problem
Create a block diagram (A.S. 4)	Foundation Skills	Math and Science	Applies mathematical and scientific procedures to solve a problem
Create a facility layout (A.S. 5)	Foundation Skills	Math and Science	Applies mathematical and scientific procedures to solve a problem

Mechanical Drafting With CAD

Tools, Equipment, and Materials List

Basic Drafting Instruments
- Compass
- Drafting pencils
- Eraser
- Scales
- T-square or drafting machine
- Triangles

Hardware
- Computer
- Keyboard
- Monitor
- Input device: mouse, joystick, graphics tablet, voice input, or other
- Plotter
- Printer

Software
- DOS, Version 5 or later
- Utility software as available
- CAD software: AutoCAD, CadKey, Microstation, Design CAD, VersaCAD, CADUM, or as selected Windows for DOS and utility software as needed

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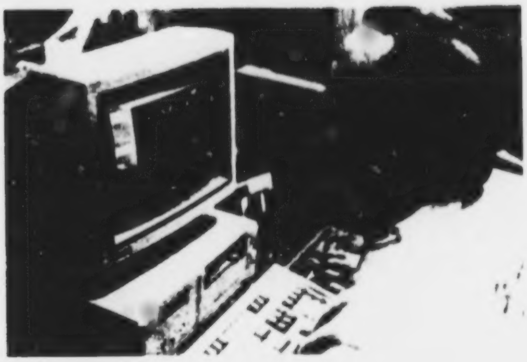


Introducation to Mechanical Drafting With CAD
Unit 1

Objective Sheet

Unit Objective

After completing this unit, the student should be able to evaluate a mechanical drawing and evaluate services from a professional organization. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to mechanical drafting with CAD with their correct definitions.
2. Match mechanical CAD drafting job titles with their descriptions.
3. Complete statements about industries that employ mechanical CAD drafters.
4. Select true statements about guidelines for planning a mechanical CAD drafting career.
5. Complete statements about guidelines for becoming a good CAD operator.
6. Match CAD skill levels with their workplace applications.
7. Complete statements about qualifications employers look for in a mechanical CAD drafter.
8. Select true statements about career outlooks for mechanical CAD drafters.
9. Complete statements about career options for mechanical CAD drafters.
10. Select true statements about professional organizations and their benefits to CAD students.

Objective Sheet

11. Evaluate a mechanical drawing. (Assignment Sheet 1)

12. Evaluate services from a professional organization. (Assignment Sheet 2)

Introduction to Mechanical Drafting with CAD
Unit 1

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for enrichment of exceptional students as well as accommodation of special needs students.

4. Make transparencies from the transparency masters included with this unit. These appear in the teacher guide only and are designed to be used with the following objectives:

   TM 1—Industries That Employ Mechanical Drafters (Objective 3)
   TM 2—Career Opportunities (Objectives 9 and 10)

5. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.

6. Develop teaching plan. Adjust for different learning styles.

7. Make copies of Unit Evaluation Form.

Delivery and Application

8. Provide students with unit of instruction.

9. Discuss unit and specific objectives.

10. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

12. Make copies of the written test. Add or modify test items as needed.

Suggested Activities

13. Give written test.

14. Compile assignment sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignments.

15. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Treat the entire unit as a career-oriented activity. Localize your instruction by gathering information about the companies or industries in your area who employ mechanical CAD drafters and invite employees or owners of those companies to talk to the class about career opportunities in drafting in general, and the importance of having CAD skills. Skill areas: **Personal management skills, personal and career development**.

2. Use Objectives 3 and 4 to talk with students about the necessity of integrating career thinking into their secondary schooling. Urge them to take classes in math and science so they'll be ahead of the game when they get into higher level education. Skill areas: **Personal management skills, motivation/goal setting**.

3. Review Assignment Sheet 1 carefully. Point out to students that the assignment will help determine if a student requires review in basic drafting, or what areas of basic drafting the student may need to pay special attention to. Skill areas: **Foundation skills, reading, writing,** and **math**.

4. Arrange the students in groups to work on Assignment Sheet 2. Develop a demonstration letter that the groups can follow as they prepare their own correspondence. Integrate these activities with materials from Teacher Supplement 1. Show as many magazines as time permits, and concentrate on magazine articles that are of particular interest to students. Skill areas: **Group effectiveness skills, teamwork**.

Resources Used in Developing This Unit

1. U.S. Department of Labor, Bureau of Labor Statistics. *Occupational Outlook Handbook*, 1992-1993 ed. Indianapolis, IN: JIST Works, Inc., 1992.

2. Goetsch, David L. and John A. Nelson and William S. Chalk. *Technical Drawing.CAD.Design*, 2nd ed. Albany, NY: Delmar Publishers Inc., 1989.

3. French, Thomas E., et. al. *Mechanical Drawing CAD-Communications*, 11th ed. New York, NY: Gregg Division McGraw-Hill Publishing Company, 1990.

Suggested Activities

Suggested Supplemental Resources

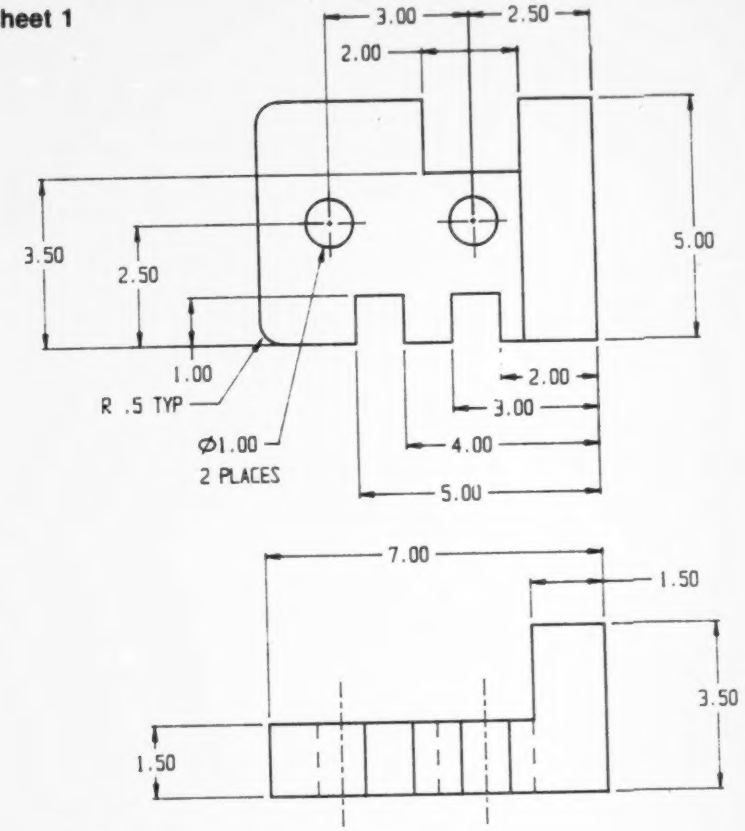
The American Drafting Design Association (ADDA) of Rockville, Maryland, is referenced in both Teacher Supplement 1 and Student Supplement 1. This organization is dedicated to a continued program of education for self-improvement and professionalism in design, drafting, and computer-aided drafting. As indicated in Student Supplement 1, ADDA does have student groups, and as indicated in Teacher Supplement 1, ADDA does publish a bimonthly magazine, *Design and Drafting News*. In addition to the magazine, ADDA publishes a Newsletter and conducts an annual National Drafting Contest.

By writing to ADDA at P.O. Box 799, Rockville, MD 20848-0799, or calling (301) 460-6875, you can get materials for student handouts or other materials to present as examples for students when they start to work on Assignment Sheet 2.

Introduction to Mechanical Drafting with CAD
Unit 1

Answers to Assignment Sheets

Assignment Sheet 1


3.00
2.50
2.00
5.00
3.50
2.50
1.00
R .5 TYP
∅1.00
2 PLACES
2.00
3.00
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1.50
3.50
1.50

Assignment Sheet 2

Evaluated according to criteria written in the assignment sheet.

Introduction to Mechanical Drafting with CAD
Unit 1

Answers to Written Test

1. a. 3
   b. 6
   c. 1
   d. 5
   e. 7
   f. 2
   g. 4

2. a. 8
   b. 3
   c. 5
   d. 7
   e. 1
   f. 9
   g. 6
   h. 2
   i. 4

3. a. Exercise
   b. Production
   c. Domestic
   d. Department of Defense
   e. A variety of
   f. Other visual media graphics
   g. Garden

4. b, c, d

5. a. Principles
   b. Often required
   c. In a high tech environment

6. a. 2
   b. 1
   c. 3

7. a. Universities
   b. Science
   c. In the workplace

8. c, d

9. a. Science
   b. Creativity
   c. Creative powers
   d. Solid modeling skills

10. a, c

Introduction to Mechanical Drafting with CAD
Unit 1

Written Test

Name ______________________________ Date ____________ Score ________

1. Match the terms on the right with their correct definitions.

_____a. An engineer or technician who is creative, inventive, and has a technical specialty

_____b. Classification according to an industry's level of engineering complexity

_____c. Design of tools, fixtures, and machines for manufacturing a product

_____d. A technician or engineering specialist who works in either product design and/or manufacturing design

_____e. The drafting of mechanical parts and assemblies using CAD and/or a drafting board so that a manufacturing process can efficiently produce a product

_____f. A specialist in details of technically solving an engineering problem; works as a liaison between engineers and technicians

_____g. Craftworkers, technicians, technologists, engineers, and scientists organized as a group to solve complex technical problems in a manufacturing environment

1. Manufacturing design
2. Technologist
3. Designer
4. Technological team
5. Mechanical designer
6. Level of technology
7. Mechanical CAD drafting

Written Text

2. Match mechanical CAD drafting job titles with their descriptions. Place the number of the job title in the blank beside its description.

______a. A beginning drafter who traces or revises other drawings or repairs or redraws damaged drawings; works under supervision with limited CAD operations

______b. A drafter with experience enough to make simple detail and assembly drawings and sketches; works with some supervision with full range of basic CAD functions and limited macro and CAD programming skills

______c. An experienced drafter who can work alone with drawings and sketches, who works well with reference materials and field notes, and has a good command of critical drafting standards; has full range of advanced CAD operations including macro and CAD programming skills

______d. An experienced drafter who handles design drafting details, works with layouts, and completes many calculations; usually has some supervisory duties; performs advanced CAD operations including macros and CAD programming skills

______e. An experienced drafter who checks all final drawings, is responsible for such errors, and for routing drawings to proper departments; has advanced CAD skills along with macro and CAD programming skills

______f. An experienced drafter good at design concepts; handles design assignments with minimum supervision, and frequently has a two-year associate degree in design and drafting; may have increased supervisory duties along with CAD skills and macro and CAD programming skills

1. Checker
2. Senior design technologist
3. Junior drafter
4. Chief design drafter
5. Drafter
6. Design technologist
7. Senior drafter
8. Trainee
9. Design drafter technician

Written Test

_______g. An experienced drafter who works with an engineering staff; almost always has a two- or four-year degree in design and drafting or mechanical design, and has increased supervisory duties; advanced CAD operations in more then one CAD program along with CAD programming skills

_______h. A drafter with several years experience who runs cost analysis, coordinates production deadlines, and works with industrial engineers for both cultural and environmental projects; usually has a four-year degree in mechanical design technology or engineering; advanced CAD operations in more then one CAD program along with CAD programming skills

_______i. A seasoned drafter who hires and fires personnel, hands out assignments, is in charge of design standards, and even helps with purchasing and the budget; almost always has a four-year degree in mechanical design technology or engineering; advanced CAD operation, networking skills, and mainframe CAD experience

3. Complete statements about industries that employ mechanical CAD drafters. Circle the material that best completes each of the following statements.

   a. The majority of mechanical drafters are employed by durable goods manufacturing companies, jobs range from the design of home appliances to (**exercise**, **military**) equipment.

   b. Mechanical drafters also work in transportation, oil (**storage**, **production**), pipeline transmission, and power generation facilities in a variety of jobs.

   c. The heating, ventilating, and air conditioning industries also employ many mechanical drafters who may work at jobs as varied as (**domestic**, **commercial**) heat pump design to large commercial designs for places like shopping centers.

   d. A few mechanical drafters are employed by governments at the state and local level, and mechanical drafters with the Federal Government work mostly for the (**Department of Defense**, **aircraft manufacturer**).

Written Test

e. Mechanical drafters work for both domestic and military contractors in (**a variety of**, **limited**) activities that range from ship building and aerospace design to power generation and electronics.

f. A few mechanical drafters work for companies that specialize in such things as environmental architecture and the world of entertainment, especially television and (**other visual media graphics**, **billboards**).

g. Farm equipment manufacturers employ mechanical drafters in all areas of design, maintenance, and product improvement ranging from high tech tractors to smaller lawn and (**playground**, **garden**) equipment.

4. Select true statements about guidelines for planning a mechanical CAD drafting career. Place an "X" beside each true statement.

_______a. Keep your grades about average in high school and make sure you get a high school diploma.

_______b. Get started with your drafting career as early as possible by taking courses at your high school or area vocational school; concentrate on developing your skills as a board drafter because good board skills make CAD easier to learn.

_______c. Remember that all drafting, especially CAD, has a mathematical base; take at least a year of algebra and another year of geometry.

_______d. Prepare your own options for advancement by taking engineering, engineering technology, and science courses related to drafting, courses such as mechanical design technology.

5. Complete statements about guidelines for becoming a good CAD operator. Circle the material that best completes each of the following statements.

a. Polish your skills at using the compass, dividers, triangles, and other devices required in drafting at a board; these skills will expose you to many (**principles**, **ideas**) that you will need as a CAD operator.

b. Take a typing course or teach yourself to type because keyboarding skills are (**often required**, **intensive**) in CAD operations.

c. Learn enough about computers, hardware, and software that you feel comfortable (**in a high tech environment**, **at a drawing table**) and take as many CAD and/or programming courses as your high school or area vocational school offers.

Written Test

6. Match CAD skill levels with their workplace applications. Place the number of the skill level in the blank beside the description of its application.

_______a. This is a skill level where an operator uses a computer system to create, modify, document, and display a drawing designed by an engineer.

_______b. This is a skill level where an operator uses a computer system to create, modify, document, and display a design; the operator may be responsible for some of the design, but is under the guidance of a design engineer.

_______c. This is a skill level where an operator uses a computer system to create, modify, document, and display a design under the guidance of a design engineer.

1. CADD, Computer Aided Design and Drafting
2. CAD, Computer Aided Drafting
3. CAD, Computer Aided Design

7. Complete statements about qualifications employers look for in a mechanical CAD drafter. Circle the material which best completes each of the following statements.

a. Employers definitely prefer drafting applicants who have post high school training in junior and community colleges, vocational-technical schools, or (**universities**, **the job corps**).

b. Employers are most interested in applicants who have well-developed drafting and mechanical drawing skills, a solid background in computer-aided design techniques, and courses in mathematics, (**history**, **science**), and engineering technology.

c. Because mechanical drafters work with specifications and calculations made by engineers and scientists, employers look for applicants with good basic skills in reading, writing, math, and communications skills, especially the ability to communicate with coworkers and other professionals (**in the workplace**, **over the telephone**).

Written Test

8. Select true statements about career outlooks for mechanical CAD drafters. Place an "X" beside each true statement.

_______a. The demand for almost all kinds of drafters will increase through the year 2005, but the demand for CAD drafters will decrease a little because as CAD systems become more expensive, their use is leveling off.

_______b. Latest statistic available from the Department of Labor indicate that in the early 1990s, the median annual earnings of drafters who worked full time, year round was more than $45,000.

_______c. Among working drafters, about one-third work as mechanical drafters with durable goods manufacturing companies such as machinery, electrical equipment, and fabricated metals.

_______d. Modern CAD drafters may experience eyestrain and discomfort from sitting long hours at a drafting board or a CAD workstation, but for the most part, CAD drafters work in clean, well-lighted facilities with the seasonal comforts of heating and air conditioning.

9. Complete statements about career options for mechanical CAD drafters. Circle the material that best completes each of the following statements.

a. Skills in mechanical drafting with CAD can open the door to several areas where workers prepare or analyze detailed drawings and make precise calculations and measurements; most of the skills are common to application engineers, engineering technicians, and (**science**, **electronic**) technicians.

b. Other advancement opportunities include tool designer and product designer, jobs where an experienced CAD operator can utilize (**creativity**, **good system skills**).

c. Other career options include illustrator or graphic designer; both areas demand good CAD skills, but (**creative powers**, **hard work**) can turn these jobs into "sky's the limit" adventures.

d. The variety of options is almost unlimited, but two busy areas include the electronics CAD operator and the aircraft and automotive industries where (**solid modeling skills**, **2-D skills**) are in high demand.

Written Test

10. Select true statements about professional organizations and their benefits to CAD students. Place an "X" beside each true statement.

______a. Professional organizations in drafting are dedicated to helping their membership stay up to date with state-of-the-art information and other education efforts dedicated to specific areas of CAD and drafting.

______b. Only a few professional organizations have student groups or chapters, but being a member will permit a student to meet new life-long friends and to network with modems or fax machines to find job openings, in fact to develop a life-long network to insure future employment opportunities.

______c. Keeping and filing materials from professional organizations can help a student (or any drafter) build a useful, contemporary reference library, and in some cases, take certification tests to become certified.

***Permission to duplicate this test is granted.**

Introduction to Mechanical Drafting with CAD
Unit 1

Unit Evaluation Form

Student Name ________________________________ Unit Rating ____________

Assignment Sheet 1—Evaluate a Mechanical Drawing Rating ______

Comments: ____

____

Assignment Sheet 2—Evaluate Service From a Professional Organization Rating ______

Comments: ____

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

Teacher Signature ________________________________ Date ____________

Student Signature ________________________________ Date ____________

***Permission to duplicate this form is granted.**

Introduction to Mechanical Drafting with CAD
Unit 1

Teacher Supplement 1—Magazines and Reference Materials

1. *Cadence*
12611 Research Boulevard, Suite 367
Austin, TX 78759-9990

2. *Designnet*
P.O. Box 1553
Riverton, NJ 08077-9553

3. *CADalyst*
650 South Clark
Chicago, IL 60605

4. *Machine Design*
1100 Superior Avenue
Cleveland, OH 44197-8024

5. *Manufacturing Engineer*
P.O. Box 930
Dearborn, MI 48121-0930

6. *Designfax*
P.O. Box 1151
Skokie, IL 60076-9917

7. *Design and Drafting News*
P.O. Box 799
Rockville, MD 20848-0799

Industries That Employ Mechanical CAD Drafters

Transportation and Communication

Oil and Pipeline

Military and Ship Building

Manufacturing and Material Fabrication

Aerospace and Electronics

Power Generation and Environmental

Farm Machinery

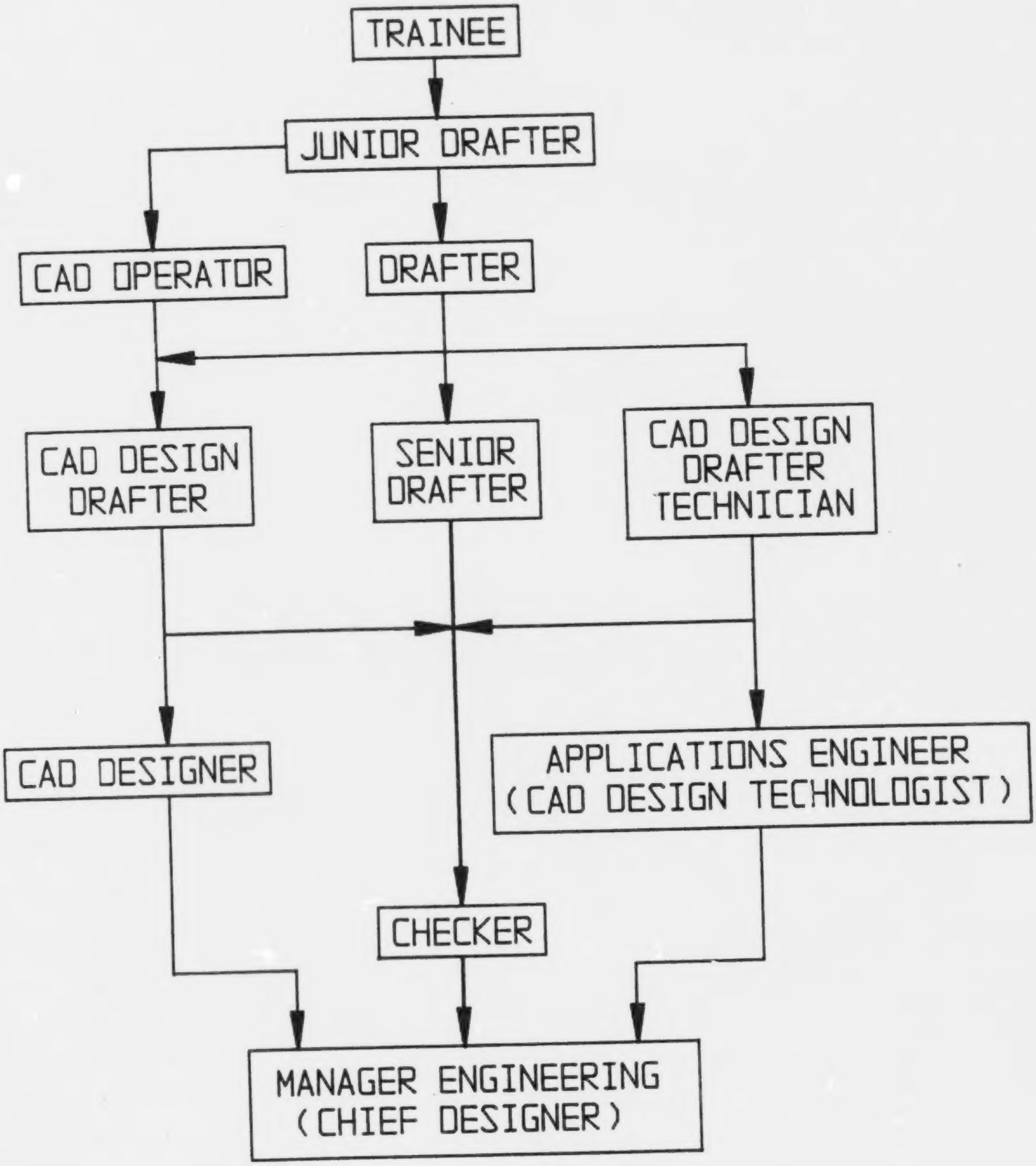
Consumer Goods

Architectural

Entertainment

HVAC (Heating, Ventilating, and Air Conditioning)

Promotional Opportunities



TRAINEE

JUNIOR DRAFTER

CAD OPERATOR

DRAFTER

CAD DESIGN DRAFTER

SENIOR DRAFTER

CAD DESIGN DRAFTER TECHNICIAN

CAD DESIGNER

APPLICATIONS ENGINEER (CAD DESIGN TECHNOLOGIST)

CHECKER

MANAGER ENGINEERING (CHIEF DESIGNER)

Introduction to Mechanical Drafting with CAD
Unit 1

Information Sheet

1. **Terms and definitions**

   a. **Designer** — An engineer or technician who is creative, inventive, and has a technical specialty

   b. **Level of technology** — Classification according to an industry's level of engineering

      Examples: Low tech—lawnmower manufacturer, medium tech—ditch digging manufacturer, and high tech—aircraft manufacturer

   c. **Manufacturing design** — Design of tools, fixtures, and machines for manufacturing a product

      Examples: Tool designer, machine designer

   d. **Mechanical CAD drafting** — The drafting of mechanical parts and assemblies using CAD and/or a drafting board so that a manufacturing process can efficiently produce a product

   e. **Mechanical designer** — A technician or engineering specialist who works in either product design and/or manufacturing design

   f. **Technological team** — Craftworkers, technicians, technologists, engineers, and scientists organized as a group to solve complex technical problems in a manufacturing environment

   g. **Technologist** — A specialist in details of technically solving an engineering problem; works as a liaison between engineers and technicians

      Example: Normally called an applications engineer

2. **Mechanical CAD drafting job titles and their descriptions**

   a. **Trainee** — A beginning drafter who traces or revises other drawings or repairs or redraws damaged drawings; works under supervision with limited CAD operations

   b. **Junior drafter** — A drafter with experience enough to make simple detail and assembly drawings and sketches; works with some supervision with full range of basic CAD functions and limited macro and CAD programming skills

Information Sheet

c. **Drafter** — An experienced drafter who can work alone with drawings and sketches, who works well with reference materials and field notes, and has a good command of critical drafting standards; has full range of advanced CAD operations including macro and CAD programming skills

d. **Senior drafter** — An experienced drafter who handles design drafting details, works with layouts, and completes many calculations; usually has some supervisory duties; performs advanced CAD operations including macros and CAD programming skills

e. **Checker** — An experienced drafter who checks all final drawings, is responsible for such errors, and for routing drawings to proper departments; has advanced CAD skills along with macro and CAD programming skills

f. **Design drafter technician** — An experienced drafter good at design concepts; handles design assignments with minimum supervision, and frequently has a two-year associate degree in design and drafting; may have increased supervisory duties along with CAD skills and macro and CAD programming skills

g. **Design technologist** — An experienced drafter who works with an engineering staff; almost always has a two- or four-year degree in design and drafting or mechanical design, and has increased supervisory duties; advanced CAD operations in more then one CAD program along with CAD programming skills

h. **Senior design technologist** — A drafter with several years experience who runs cost analysis, coordinates production deadlines, and works with industrial engineers for both cultural and environmental projects; usually has a four-year degree in mechanical design technology or engineering; advanced CAD operations in more then one CAD program along with CAD programming skills

i. **Chief design drafter** — A seasoned drafter who hires and fires personnel, hands out assignments, is in charge of design standards, and even helps with purchasing and the budget; almost always has a four-year degree in mechanical design technology or engineering; advanced CAD operations, networking skills, and mainframe CAD experience

3. **Industries that employ mechanical CAD drafters**

a. The majority of mechanical drafters are employed by durable goods manufacturing companies; jobs range from the design of home appliances to exercise equipment.

Note: Durable goods are also known as consumer goods.

b. Mechanical drafters also work in transportation, oil production, pipeline transmission, and power generation facilities in a variety of jobs.

Information Sheet

c. The heating, ventilating, and air conditioning industries also employ many mechanical drafters who may work at jobs as varied as domestic heat pump design to large commercial designs for places like shopping centers.

d. A few mechanical drafters are employed by governments at the state and local level, and mechanical drafters with the Federal Government work mostly for the Department of Defense.

e. Mechanical drafters work for both domestic and military contractors in a variety of activities that range from ship building and aerospace design to power generation and electronics.

f. A few mechanical drafters work for companies that specialize in such things as environmental architecture and the world of entertainment, especially television and other visual media graphics.

g. Farm equipment manufacturers employ mechanical drafters in all areas of design, maintenance, and product improvement ranging from high tech tractors to smaller lawn and garden equipment.

4. **Guidelines for planning a mechanical CAD drafting career**

a. Keep your grades above average in high school and make sure you get a high school diploma.

b. Get started with your drafting career as early as possible by taking courses at your high school or area vocational school; concentrate on developing your skills as a board drafter because good board skills make CAD easier to learn.

c. Remember that all drafting, especially CAD, has a mathematical base; take at least a year of algebra and another year of geometry.

d. Prepare your own options for advancement by taking engineering, engineering technology, and science courses related to drafting, courses such as mechanical design technology.

5. **Guidelines for becoming a good CAD operator**

a. Polish your skills at using the compass, dividers, triangles, and other devices required in drafting at a board; these skills will expose you to many principles that you will need as a CAD operator.

b. Take a typing course or teach yourself to type because keyboarding skills are often required in CAD operations.

Information Sheet

c. Learn enough about computers, hardware, and software that you feel comfortable in a high tech environment, and take as many CAD and/or programming courses as your high school or area vocational school offers.

Note: CAD is a challenge to beginners because of the variety of software available and the complementing hardware that goes with it. Exposure to different kinds of software and hardware can lead to the versatility that CAD operators always need.

6. CAD skill levels and their workplace applications

a. **CAD, Computer Aided Drafting** — This is a skill level where an operator uses a computer system to create, modify, document, and display a drawing designed by an engineer, but CAD drawn by the operator.

b. **CADD, Computer Aided Design and Drafting** — This is a skill level where an operator uses a computer system to create, modify, document, and display a design; the operator may be responsible for some of the design, but is under the guidance of a design engineer.

c. **CAD, Computer Aided Design** — This is a skill level where an operator uses a computer system to create, modify, document, and display a design under the guidance of a design engineer but, designed by the CAD operator.

7. Qualifications employers look for in a mechanical CAD drafter

a. Employers definitely prefer drafting applicants who have post high school training in junior and community colleges, vocational-technical schools, or universities.

b. Employers are most interested in applicants who have well-developed drafting and mechanical drawing skills, a solid background in computer-aided design techniques, and courses in mathematics, science, and engineering technology.

c. Because mechanical drafters work with specifications and calculations made by engineers and scientists, employers look for applicants with good basic skills in reading, writing, math, and communications skills, especially the ability to communicate with coworkers and other professionals in the workplace.

8. Career outlooks for mechanical CAD drafters

a. The demand for almost all kinds of drafters will increase through the year 2005, but the demand for CAD drafters will increase even more because as CAD systems become less expensive, their use is increasing.

b. Latest statistic available from the Department of Labor indicate that in the early 1990s, the median annual earnings of drafters who worked full time, year round was more than $25,000.

Information Sheet

c. Among working drafters, about one-third work as mechanical drafters with durable goods manufacturing companies such as machinery, electrical equipment, and fabricated metals.

d. Modern CAD drafters may experience eyestrain and discomfort from sitting long hours at a drafting board or a CAD workstation, but for the most part, CAD drafters work in clean, well-lighted facilities with the seasonal comforts of heating and air conditioning.

9. Career options for mechanical CAD drafters

a. Skills in mechanical drafting with CAD can open the door to several areas where workers prepare or analyze detailed drawings and make precise calculations and measurements; most of the skills are common to application engineers, engineering technicians, and science technicians.

b. Other advancement opportunities include tool designer and product designer, jobs where an experienced CAD operator can utilize creativity.

c. Other career options include illustrator or graphic designer; both areas demand good CAD skills, but creative powers can turn these jobs into "sky's the limit" adventures.

d. The variety of options is almost unlimited, but two busy areas include the electronics CAD operator and the aircraft and automotive industries where solid modeling skills are in high demand.

10. Professional organizations and their benefits to CAD students

a. Professional organizations in drafting are dedicated to helping their membership stay up to date with state-of-the-art information and other education efforts dedicated to specific areas of CAD and drafting.

b. Many professional organizations have student groups or chapters, and being a member will permit a student to meet new life-long friends and to network with modems or fax machines to find job openings, in fact to develop a life-long network to insure future employment opportunities.

Information Sheet

c. Keeping and filing materials from professional organizations can help a student (or any drafter) build a useful, contemporary reference library, and in some cases, take certification tests to become certified.

Example: In the American Design and Drafting Association, you can become a Certified Drafter or a Certified Designer. In the Society of Manufacturing Engineers, you can become a Certified Manufacturing Technologist (CMFgT) or a Certified Manufacturing Engineer (CMFgE).

Note: Be sure to read Student Supplement 1 for a list of professional organizations that you might want to join or learn more about. Ask your instructor about city or state organizations that may be active in your community. These local organizations are sometimes very active and fun to be a part of.

Introduction to Mechanical Drafting with CAD
Unit 1

Student Supplement 1—Professional Organizations

1. American Design Drafting Association
P.O. Box 799
Rockville, MD 20848-0799
Phone: (301) 460-6875 *Does have student chapters

2. American Institute of Aeronautics and Astronautics
370 L'Enfant Promenade, SW
Washington, D.C. 20024
Phone: (202) 646-7400 *Does have student branches

3. American Institute of Industrial Engineers
25 Technology Park/Atlanta
Norcross, GA 30092
Phone: (404) 449-0460 *Does accept student members

4. American Society of Mechanical Engineers
345 East 47th Street
New York, NY 10017
Phone: (212) 705-7722 *Does have student sections

5. Society of Manufacturing Engineers
P.O. Box 130
1 SME Drive
Dearborn, MI 48121
Phone: (313) 271-1500 *Does have student chapters

6. National Computer Graphics Association
2722 Merrilee Drive, Suite 200
Fairfax, VA 22031
Phone: (703) 698-9600 *Does have special student activities

7. Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096-0001
Phone: (412) 776-4841 *Special affiliation for engineering students

Introduction to Mechanical Drafting with CAD
Unit 1

Assignment Sheet 1—Evaluate a Mechanical Drawing

Student Name ______________________ Overall Rating __________

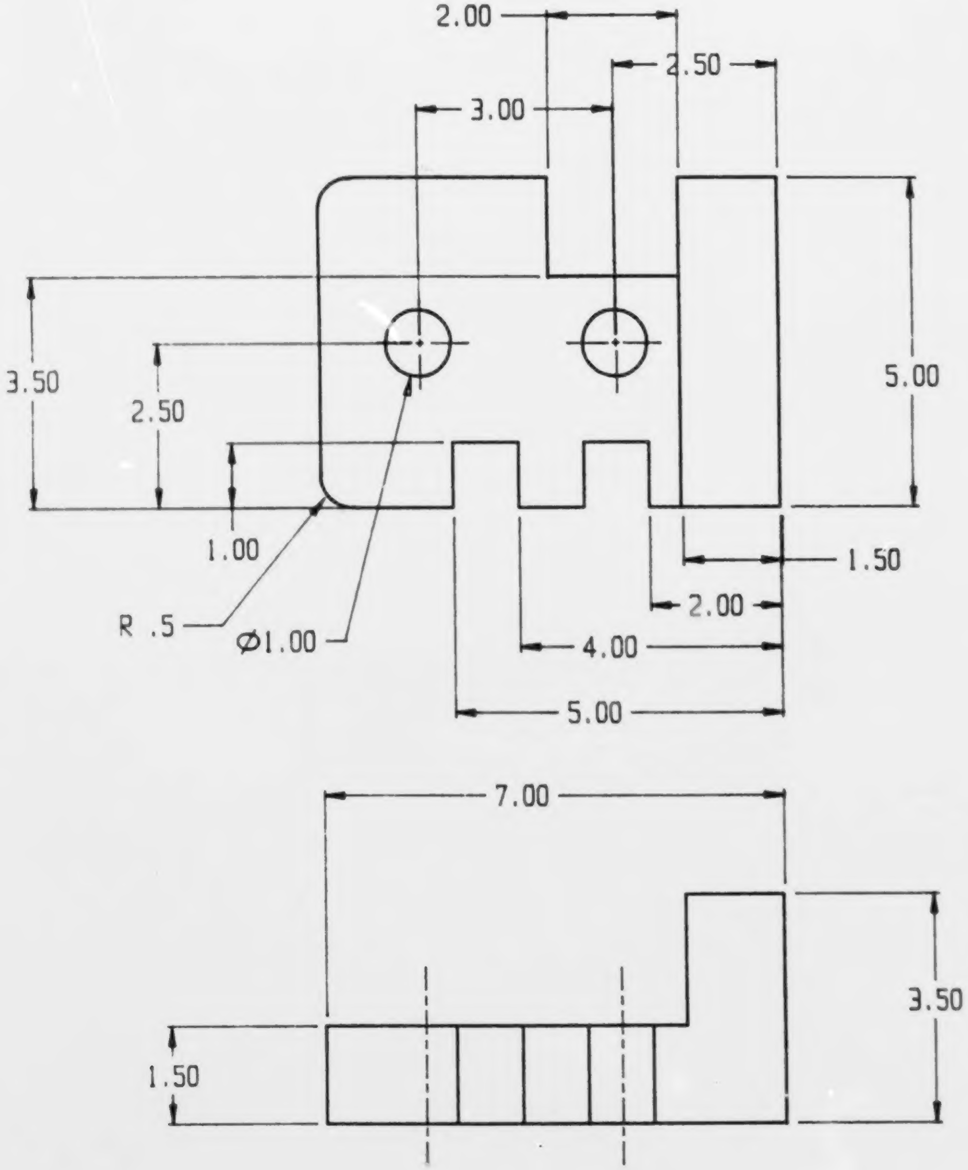
Evaluation criteria	**Rating**
Number of entries attempted	______
Number of entries with errors or problems listed	______
Quality of observations made	______

Directions: Carefully examine the mechanical drawing on the next page, and then evaluate the drawing for each of the areas listed in the evaluation form that follows.

1. Accuracy ______________________
2. Linework ______________________
3. Lettering ______________________
4. Overall Appearance ______________________
5. Dimensioning ______________________
6. Reproducibility ______________________
7. Spelling and use of abbreviations ______________________

Assignment Sheet 1

Note: Examine your observations and then turn your assignment in to your instructor for evaluation.


2.00
2.50
3.00
3.50
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5.00
1.00
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R .5
Ø1.00
2.00
4.00
5.00
7.00
3.50
1.50

Introduction to Mechanical Drafting with CAD
Unit 1

Assignment Sheet 2—Evaluate Services From a Professional Organization

Student Name ______________________ Overall Rating __________

Evaluation criteria	**Rating**
Proper contact with organization	_____
Number of services listed	_____
Student services identified	_____

Directions: Use Student Supplement 1 to select a service organization to write to. In a note or short letter, request information about the organization's activities, the extent of its operations, and special areas of interest. Make a point to ask for information about student services offered by the organization. Work with another student or other students as your instructor may direct, and prepare a brief report for the class.

Organization contacted ______________________

____

Address ______________________

____

Areas of special interest ______________________

____

____

____

____

Extent of operations (local, state, regional, national, international) ______________________

____

____

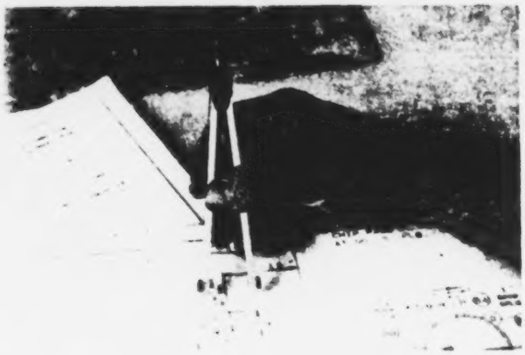
Assignment Sheet 2

Special student services ____

____

____

____



Tools and Equipment
Unit 2

Objective Sheet

Unit Objective

After completing this unit, the student should be able to compute drafting problems with a hand-held calculator, measure with scales and calipers, and measure with a micrometer and a vernier caliper. The student should demonstrate these competencies by completing the assignment and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to tools and equipment with their correct definitions.
2. Select true statements about templates and their use in mechanical drafting.
3. Match machinist precision measuring instruments with their uses.
4. Complete statements about welding measuring instruments that drafters need to know.
5. Complete statements about basic scales used in mechanical drafting.
6. Select true statements about metric scales and their use in mechanical drafting.
7. Complete statements about hand-held calculators and their uses in mechanical drafting.
8. Read micrometer settings in inches and millimeters. (Assignment Sheet 1)
9. Read vernier calipers in inches and millimeters. (Assignment Sheet 2)
10. Measure with engineer, machinist, and metric scales. (Assignment Sheet 3)
11. Compute mechanical drafting problems with a hand-held calculator. (Assignment Sheet 4)

Objective Sheet

12. Measure with a micrometer. (Job Sheet 1)
13. Measure with a vernier caliper. (Job Sheet 2)

Tools and Equipment
Unit 2

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for enrichment of exceptional students as well as accommodation of special needs students.

4. Make transparencies from the transparency masters included with this unit. These appear in the teacher edition only and are designed to be used with the following objectives:

   TM 1—Reading a Micrometer (Objective 3)
   TM 2—Vernier Scales (Objective 2)
   TM 3—Mechanical Engineer Scale (Objective 5)
   TM 4—Machinist Steel Rules (Objectives 5 and 6)

5. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.

6. Develop teaching plan. Adjust for different learning styles.

7. Make copies of Unit Evaluation Form.

Delivery and Application

8. Provide students with unit of instruction.

9. Discuss unit and specific objectives.

10. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

11. Discuss the assignment and job sheets. Review criteria for evaluation of these activities.

Suggested Activities

Evaluation

12. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

13. Make copies of the written test. Add or modify test items as needed.

14. Give written test.

15. Compile assignment and job sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignments.

16. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Spend sufficient time on Objective 3 to assure that students have not just an understanding or precision measuring instruments, but a good command of their use. Demonstrate how a micrometer is used for various types of measurements. Also demonstrate the use of vernier calipers and remind students that the assignment sheets will challenge them to measure accurately with these instruments. Skill areas: **Foundation skills, science**.

2. Review basic measuring scales and demonstrate why they make mechanical drafting easier to accomplish by providing to-scale drawings in confined or restricted formats. Skill areas: **Foundation skills, math**.

3. Have both a hand-held scientific calculator and a business-type calculator on hand to demonstrate the different capacities of the two types of instruments. Skill areas: **Foundation skills, math**.

Suggested Activities

Resources Used in Developing This Unit

1. Giesecke, Frederick E., et.al. *Technical Drawing.* New York: Macmillan Publishing Company, Inc., 1993.
2. Bertoline, Gary R. *Fundamentals of CAD.* New York: Delmar Publishing, Inc., 1988.
3. McClain, Gerald R. *The CAD Survival Kit.* Stillwater, OK: The Mid-America Vocational Curriculum Consortium, 1993.
4. *Advanced Scientific Calculator Reference Manual.* Corvalis, OR: Hewlett Packard, 1989.
5. *Texas Instruments Advanced Scientific TI-81 Graphics Calculator Guidebook.* Dallas, TX: Texas Instruments, 1990.

Suggested Supplemental Resources

1. Wallach, Paul. *Metric Drafting.* Encino, CA: Glencoe Publishing Co., Inc., 1979.
2. *Walden's Metric Primer for Single Service Products.* Oradel, NJ: Walden-Mott Corp., 1976.

   Note: The *Metric Primer* is probably available at libraries around the country. It is an exceptional text and highly recommended for both engineering and CAD drafting students.

Instructions for Evaluating Student Performance

When the student is ready to perform a specific task, obtain a copy of the job sheet which may be found in either the teacher or student edition. Then observe the student performing the procedure.

Process evaluation—Place a mark in the box to the left of each designated checkpoint if the student has satisfactorily achieved the step(s) for each checkpoint area. If the student is unable to correctly complete the procedure, have the student review the materials and try again.

Product evaluation—Once the student has satisfactorily completed the procedure, rate the student product (outcome) using the criteria which have been provided as part of the job sheet. If the student's product is unacceptable, have the student review the materials and submit another product for evaluation.

Suggested Activities

Sample performance evaluation keys have been provided below. Many other keys are available. Select one rating (grading scale) which best fits your program needs.

Option A

4 - Skilled—Can perform job with no additional training.
3 - Moderately skilled—Has performed job during training program; limited additional training may be required.
2 - Limited skill—Has performed job during training program; additional training is required to develop skill.
1 - Unskilled—Is familiar with process, but is unable to perform job.

Option B

Yes—Can perform job with no additional training.

No—Is unable to perform job satisfactorily.

Tools and Equipment
Unit 2

Answers to Assignment Sheets

Assignment Sheet 1

A.
1. 0.871
2. 0.226
3. 0.184
4. 0.291
5. 0.086
6. 0.0023
7. 0.500
8. 0.342
9. 0.047
10. 0.125
11. 0.613
12. 0.250
13. 0.012

B.
1. 6.75 mm
2. 3.68 mm
3. 8.78 mm
4. 14.26 mm
5. 10.61 mm
6. 4.35 mm

Assignment Sheet 2

A.
1. .321
2. 3.067

B.
1. 4.603
2. 1.317

C.
1. 18.22
2. 20.62
3. 6.70
4. 34.64

Answers to Assignment Sheets

Assignment Sheet 3

	MECHANICAL ENGINEER SCALE			METRIC SCALE (mm) (One place)		
	DECIMAL	FRACTIONS				
	1" = 1" (2 Places)	½" = 1" (Nearest 32nd)	¼" = 1" (Nearest 16th)	1:1 (One place)	1:2 (Nearest mm)	1:5 (Nearest mm)
A	3.89	$7\frac{25}{32}$	$15\frac{9}{16}$	98.8	198	494
B	3.31	$6\frac{5}{8}$	$13\frac{1}{4}$	84.0	168	420
C	5.39	$10\frac{25}{32}$	$21\frac{9}{16}$	136.9	274	680
D	36	$\frac{23}{32}$	$1\frac{7}{16}$	9.2	18	46
E	2.41	$4\frac{13}{16}$	$9\frac{5}{8}$	60.5	121	303
F	4.33	$8\frac{21}{32}$	$17\frac{5}{16}$	109.7	219	549
G	4.98	$10\frac{31}{32}$	$19\frac{15}{16}$	125.6	251	628
H	1.38	$2\frac{3}{4}$	$5\frac{1}{2}$	35.0	70	175

	MACHINIST STEEL RULE (Full Scale)			
	FRACTIONS (Nearest $\frac{1}{64}$)	DECIMAL (Nearest .02)	METRIC (Nearest mm)	METRIC (Nearest ½ mm)
A	$3\frac{57}{64}$	3.88	99	99.0
B	$3\frac{5}{16}$	3.40	84	84.0
C	$5\frac{25}{64}$	5.40	137	137.0
D	$\frac{23}{64}$	.36	9	9.0
E	$2\frac{13}{32}$	2.40	61	60.5
F	$4\frac{21}{64}$	2.32	110	109.5
G	$4\frac{63}{64}$	4.98	126	125.5
H	$1\frac{3}{8}$	1.38	35	35.0

Answers to Assignment Sheets

Assignment Sheet 4

A. 1. $X = 68.5$
   2. $X = 1.28$
   3. $X = 4.64$

B. 1. $R = 20.2485''$
   2. $X = 9.3808''$

C. 1. $A = 31.3707$ in.^{2}
   2. $A = 63.6173$ in^2
   3. $C = 2.7489''$
   4. $C = 10.9956''$

D. 1. $A = 95.48$ in.^{2}
   2. $D = 9.916$

Tools and Equipment
Unit 2

Answers to Written Test

1. a. 4
   b. 6
   c. 8
   d. 1
   e. 7
   f. 3
   g. 5
   h. 2

2. a, b, c, d

3. a. 8
   b. 5
   c. 12
   d. 14
   e. 1
   f. 10
   g. 4
   h. 2
   i. 13
   j. 11
   k. 6
   l. 3
   m. 7

4. a. Fabricated
   b. Common
   c. Good rule
   d. Favorite
   e. Inside

5. a. M
   b. E

6. b, c

7. a. Portability
   b. Primary
   c. Secondary, secondary
   d. Secondary
   e. Basic
   f. Scientific
   g. Scientific, scientific

Tools and Equipment
Unit 2

Written Test

Name ______________________ Date ______________ Score __________

1. Match the terms on the right with their correct definitions.

_____a. The hardware, software, and functioning area used by a mechanical CAD drafter or designer to communicate with a computer system

_____b. Points, lines, or other geometric shapes, assumed to be exact, from which the location of geometric form or features of a part may be estimated

_____c. A portable calculating device used to solve mathematical problems

_____d. The arrangement of a sequence of operations

_____e. Instruments machinists use for measuring

_____f. A thin, flat, plastic tool with various size openings of different shapes used to expedite the drawing of standard features

_____g. Preprinted letters, symbols, and shading that can be cut out and pasted or rubbed onto drawings to save drafting time

_____h. An instrument used as a standard of reference when drawing an object to a proportional size

1. Logic
2. Scale
3. Template
4. CAD workstation
5. Transfer artwork
6. Datums
7. Precision instruments
8. Hand-held calculator

Written Test

2. Select true statements about templates and their uses in mechanical drafting. Place an "X" beside each true statement.

______a. General purpose templates permit a drafter to quickly draw standard geometric shapes such as circles, squares, triangles, hexagons, octagons, and also arrows.

______b. Welding templates are used for placing standard welding symbols onto drawings.

______c. Templates for threaded fasteners permit quick placement of symbols for nuts, bolts, screws, and threads, and there are special templates for springs.

______d. Three-dimensional templates provide a handy way to draw projection ellipses, isometric ellipses, and both isometric and projection hexagon bolt heads and nuts.

______e. The symbol libraries available for most CAD systems are similar to mechanical templates, but their application is totally different.

3. Match machinist precision measuring instruments with their uses. Place the number of the instrument in the blank beside the description of its use.

______a. Used in various formats to measure distances

______b. Used to accurately measure outside objects

______c. Used to accurately measure inside objects

______d. Used to measure the depth of slots or holes from datum surfaces

______e. Used for approximate measurements of external and internal distances

______f. Used for accurate measurements of external and internal distances

______g. Used to obtain a continuous reading and for dial test indicators for gaging

1. Calipers
2. Height transfer gage for surfaces
3. Plug gage
4. Dial caliper
5. Outside micrometer
6. Snap gage
7. Divider
8. Rules
9. Optical Comparator
10. Vernier calipers

Written Test

_____h. Used for accurate parallel surface measurements

_____i. Used for accurate angle measurements

_____j. Used to measure alignment, eccentricity, or deviations on surfaces

_____k. Used for plain external dimensions for "go" or "no go" gaging

_____l. Used for internal dimensions of holes for "go" or "no go" gaging

_____m. Used for transferring dimensions and for scribing circles

_____n. Uses a master or lines on a screen to compare finished parts

11. Dial indicator gage
12. Inside micrometer
13. Sine bar
14. Depth micrometer

4. Complete statements about welding measuring instruments that drafters need to know. Circle the material that best completes each of the following statements.

   a. Knowing how a product is (**designed**) (**fabricated**) helps a drafter better understand the importance of measuring devices and how they are used in the workplace.

   b. Since welding applications are (**common**) (**less used**) in mechanical drafting, the tools welders used to measure materials are important tools for the drafter to know.

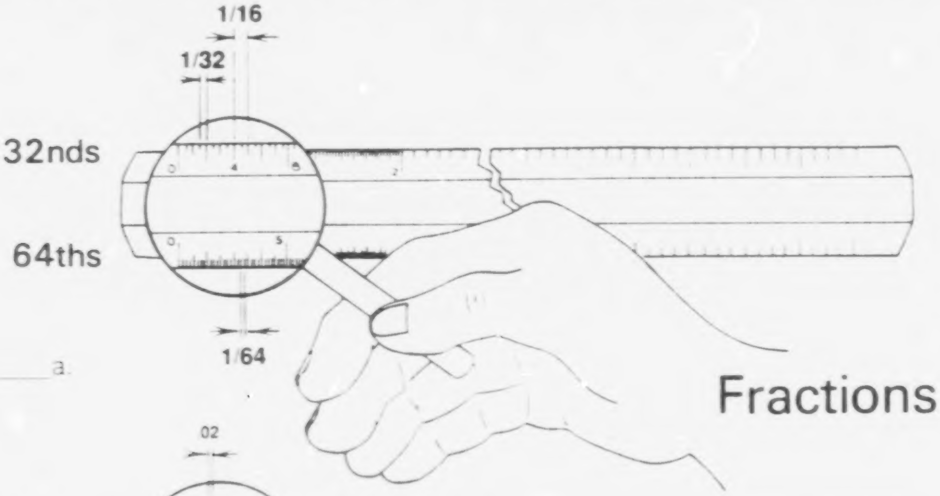
   c. The steel square is not just a square, it is a (**framing device**) (**good rule**), and the combination square not only measures angles and bevels, it helps a welder center a pipe.

   d. Steel rules used in welding measurement are usually a yard long, hand-held 25-foot retractable tapes are welders (**least durable**) (**favorite**) tapes, and fabric tapes are used for longer measurements.

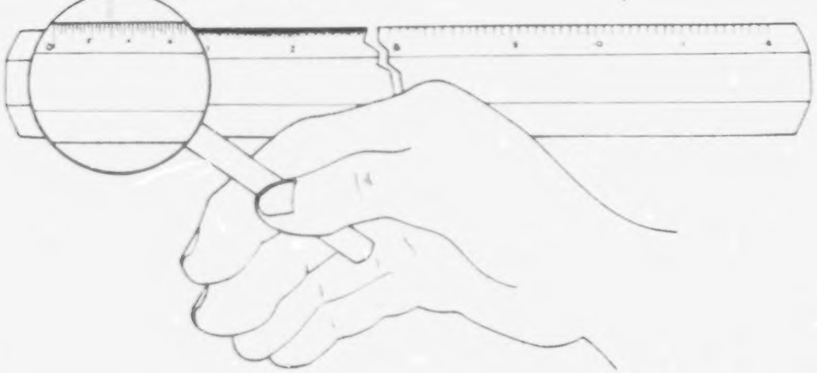
   e. Both (**vernier**) (**inside**) and outside calipers are used by welders to measure everything from plug welds to pipe diameters.

Written Test

5. Differentiate between basic scales used in mechanical drafting. Place an "E" below the illustration of an engineer scale, and an "M" below the illustration of a machinist scale.



_______a.



_______b.

6. Select true statements about metric scales and their use in mechanical drafting. Place an "X" beside each true statement.

_______a. Since the millimeter is the primary unit of measurement on a metric scale, the primary metric scale has divisions equal to 10mm.

_______b. A metric scale may also have divisions equal to ½ millimeters where each division is equal to .5mm.

_______c. Metric scales come in various ratios, 1:1, 1:2, 1:3, 1:5, and 1:10, and the ratios should be read as 1mm equals 1mm, 1mm equals 5mm, 1mm equals 10mm, etc.

Written Test

7. Complete statements about hand-held calculators and their uses in mechanical drafting. Circle the material that best completes each of the following statements.

   a. Because of (**speed**) (**portability**) and small size, a hand-held calculator is one piece of equipment a mechanical drafter uses often.

   b. The (**secondary**) (**primary**) functions on a hand-held calculator are the common mathematical functions: add, subtract, multiply, and divide.

   c. The (**secondary**) (**primary**) functions on a hand-held calculator permit an operator to perform (**secondary**) (**primary**) functions which include finding the square of a number, the square root of a number, or finding a reciprocal.

   d. Other (**primary**) (**secondary**) functions of a hand-held calculator include: logarithms, trigonometric antilogarithm, hyperbolic, angular mode for radians and degrees, and memory storage.

   e. Some hand-held calculators also have computer programming capabilities that mirror computer commands for (**almost all**) (**basic**) programming functions.

   f. Some calculators work with an algebraic or business sequence, and others work with a (**computer**) (**scientific**) or "Lukasciewicz" sequence.

   g. The hand-held calculator with a (**scientific**) (**business**) sequence will provide a drafter with a better tool for computing complex drafting problems because the base of the (**scientific**) (**business**) sequence is an "order of operations" that provides faster answers.

***Permission to duplicate this test is granted.**

Tools and Equipment
Unit 2

Unit Evaluation Form

Student Name ______________________ Unit Rating ________

Assignment Sheet 1—Read Micrometer Settings in Inches and Millimeters Rating ______

Comments: ____

____

Assignment Sheet 2—Read Vernier Calipers in Inches and Millimeters Rating ______

Comments: ____

____

Assignment Sheet 3—Measure With Engineer, Machinist, and Metric Scales Rating ______

Comments: ____

____

Assignment Sheet 4—Compute Mechanical Drafting Problems With a Hand-Held Calculator Rating ______

Comments: ____

____

Job Sheet 1—Measure With a Micrometer Rating ______

Comments: ____

____

Job Sheet 2—Measure With a Vernier Caliper Rating ______

Comments: ____

____

Unit Evaluation Form

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

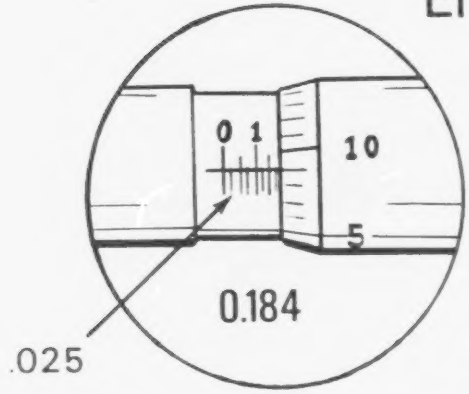
Teacher Signature ______________________________ Date ____________

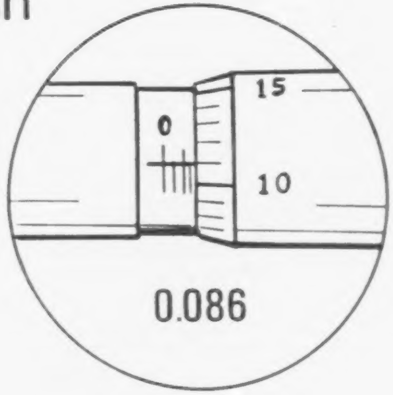
Student Signature ______________________________ Date ____________

*Permission to duplicate this form is granted.

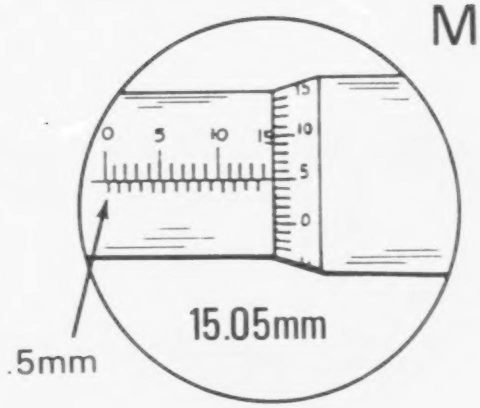
Reading a Micrometer

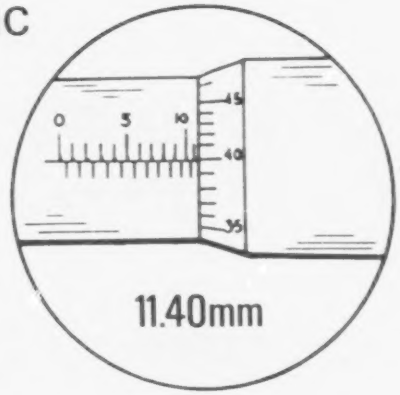
English


0 1
10
5
0.184
.025

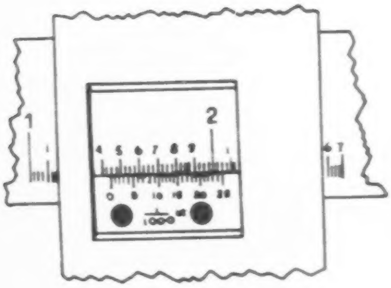


Metric

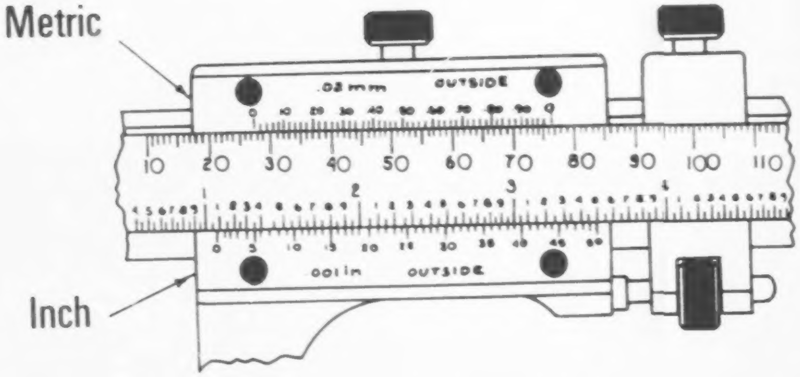

0 5 10 15
15
10
5
0
15.05mm
.5mm


0 5 10
45
40
35
11.40mm

Vernier Scales

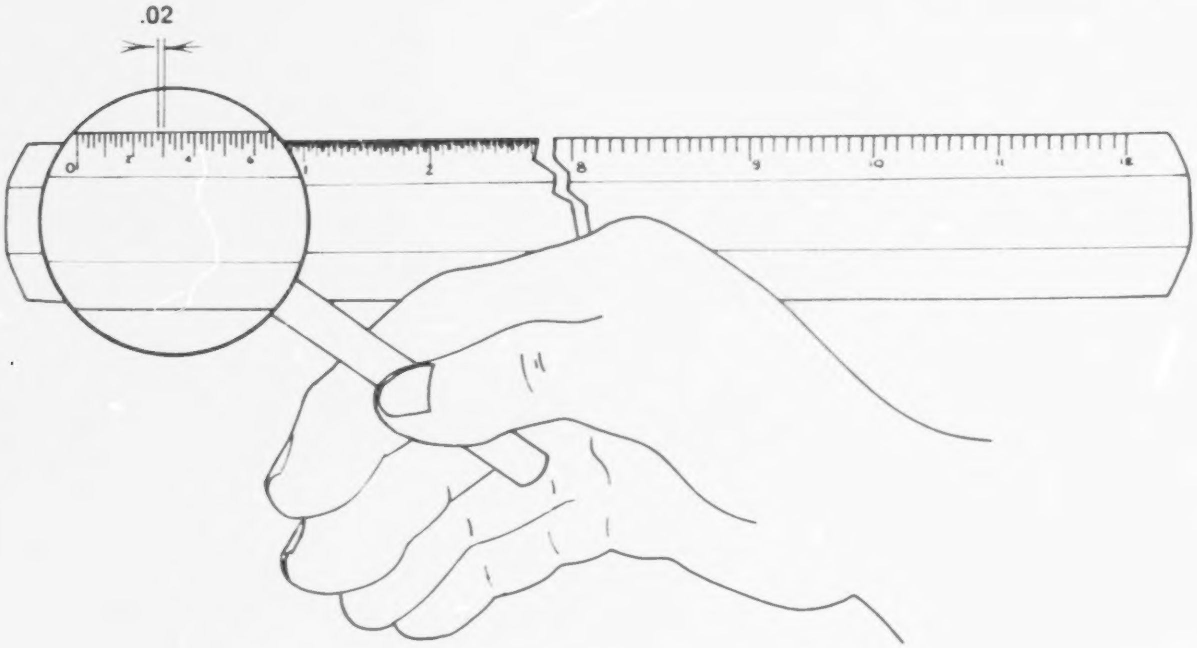

1
2
4 5 6 7 8 9
0 5 10 15 20 25
1/1000"

25 Division
Inch Caliper

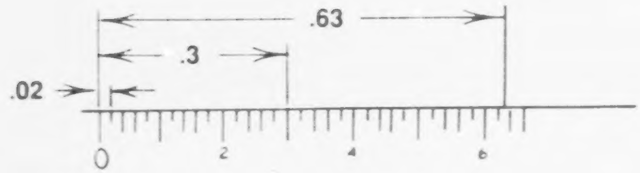

Metric
.02 mm
OUTSIDE
0 10 20 30 40 50 60 70 80 90 0
10 20 30 40 50 60 70 80 90 100 110
1 2 3 4
0 5 10 15 20 25 30 35 40 45 50
.001 in
OUTSIDE
Inch

50 Division Inch
and Metric Caliper

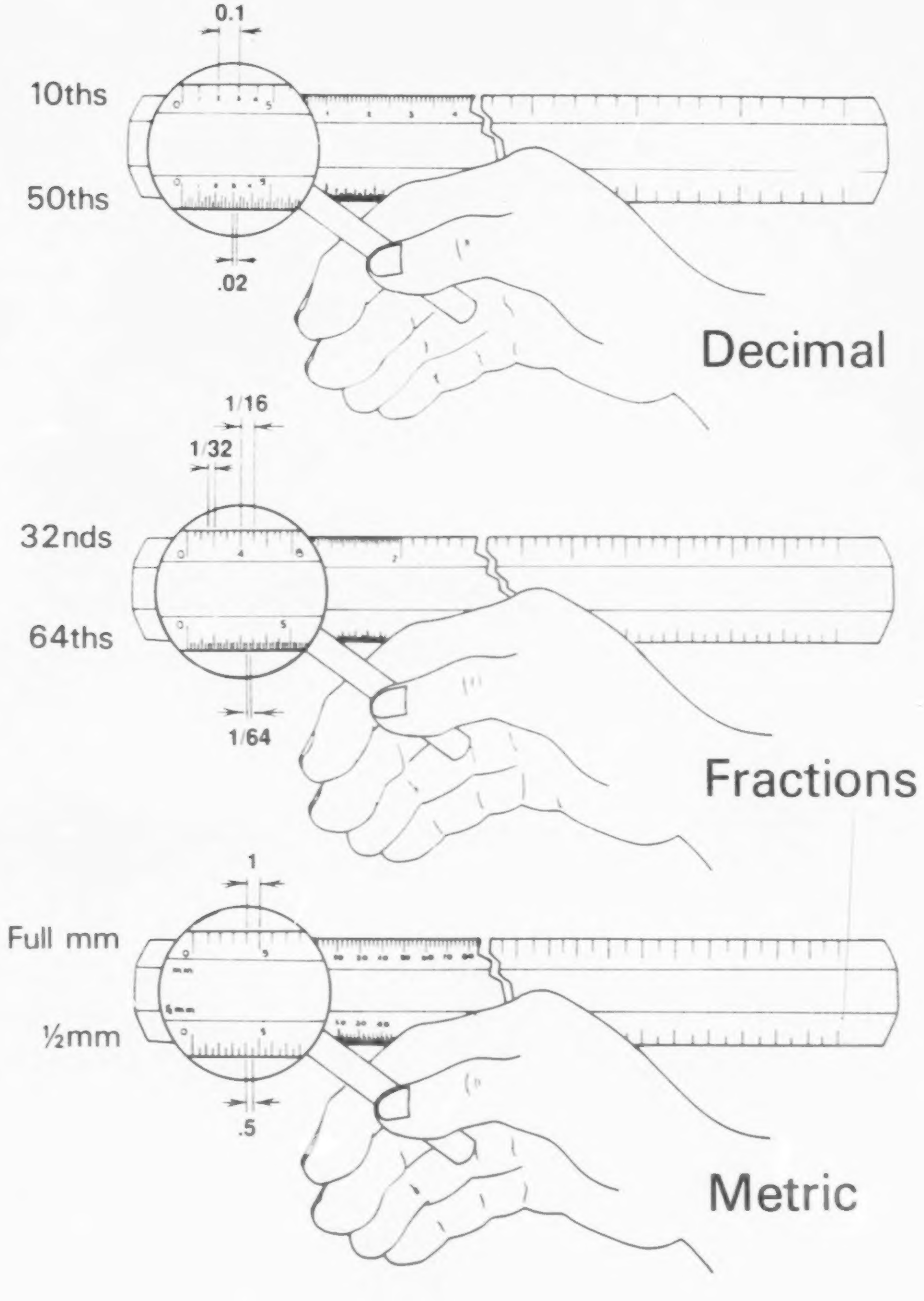
Mechanical Engineer Scale


.02
0
2
4
6
1
2
8
9
10
11
12

Decimal



Machinist Steel Rules


0.1
10ths
50ths
.02
Decimal
1/16
1/32
32nds
64ths
1/64
Fractions
1
Full mm
½mm
.5
Metric

Tools and Equipment
Unit 2

Information Sheet

1. **Terms and definitions**

   a. **CAD workstation** — The hardware, software, and functioning area used by a mechanical CAD drafter or designer to communicate with a computer system

   b. **Datums** — Points, lines, or other geometric shapes, assumed to be exact, from which the location of geometric form or features of a part may be estimated

   c. **Hand-held calculator** — A portable calculating device used to solve mathematical problems

   d. **Logic** — The arrangement of a sequence of operations

   e. **Precision instruments** — Instruments machinists use for measuring

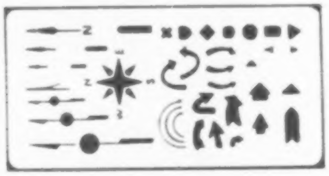
   f. **Template** — A thin, flat, plastic tool with various size openings of different shapes used to expedite the drawing of standard features

   g. **Transfer artwork** — Preprinted letters, symbols, and shading that can be cut out and pasted or rubbed onto drawings to save drafting time

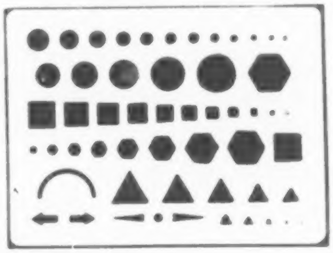
   h. **Scale** — An instrument used as a standard of reference when drawing an object to a proportional size

2. **Templates and their uses in mechanical drafting**

   a. General purpose templates permit a drafter to quickly draw standard geometric shapes such as circles, squares, triangles, hexagons, octagons, and also arrows.



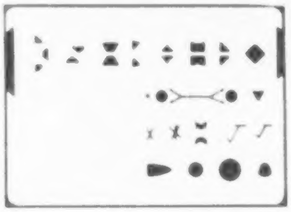
Professional Arrow



General Purpose

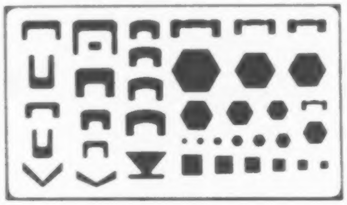
Information Sheet

b. Welding templates are used for placing standard welding symbols onto drawings.

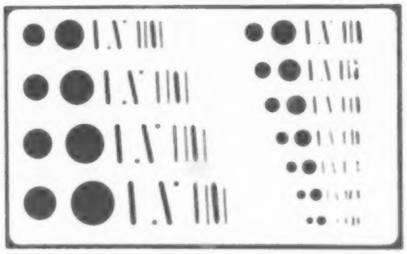


Welding Symbols

c. Templates for threaded fasteners permit quick placement of symbols for nuts, bolts, screws, and threads, and there are special templates for springs.



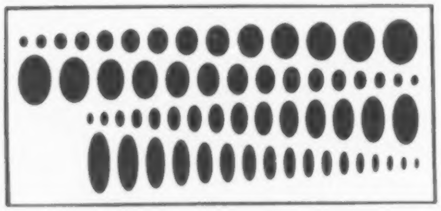
Nut, Bolt, and Screw Template



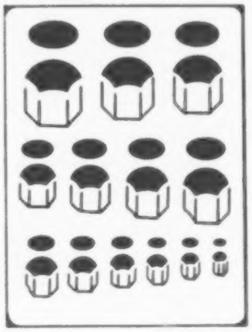
Springs and Screw Threads

Information Sheet

d. Three-dimensional templates provide a handy way to draw projection ellipses, isometric ellipses, and both isometric and projection hexagon bolt heads and nuts.



Master Ellipse

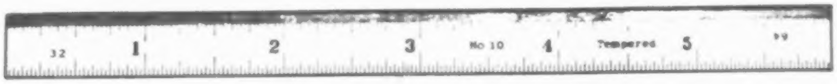


Isometric Hexagon
Heads and Nuts

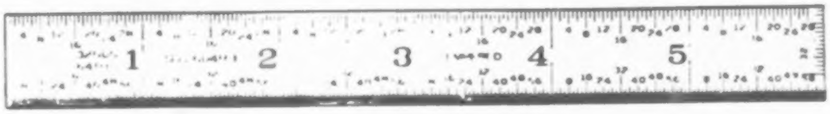
e. The symbol libraries available for most CAD systems are the electronic equivalents of the mechanical templates used in board drafting.

3. **Machinists precision measuring instruments and their uses**

a. **Rules** — Used in various formats to measure distances



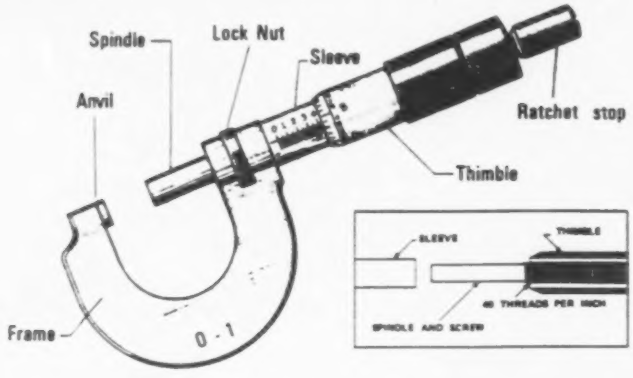
Narrow Flexible Rule



Steel Rule

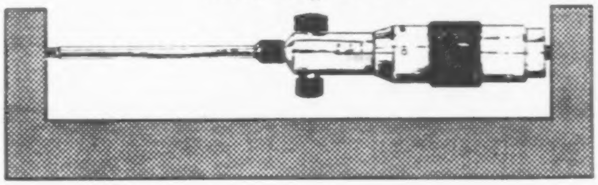
Information Sheet

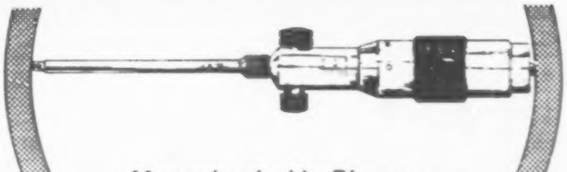
b. **Outside micrometer** — Used to accurately measure outside objects


Spindle
Lock Nut
Sleeve
Anvil
Ratchet stop
Thimble
Frame
0 - 1
SLEEVE
THIMBLE
40 THREADS PER INCH
SPINDLE AND SCREW

c. **Inside micrometer** — Used to accurately measure inside objects

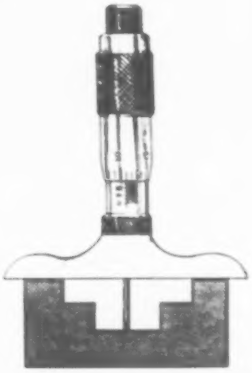
Measuring Widths



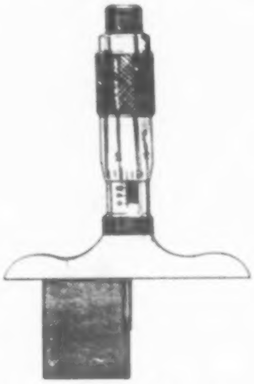


Measuring Inside Diameters

d. **Depth micrometer** — Used to measure the depth of slots or holes from datum surfaces



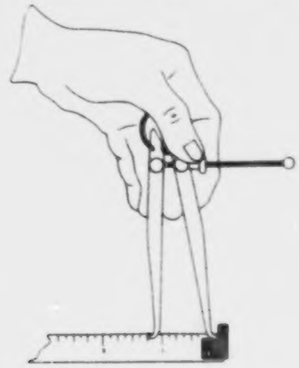
Measuring Depth of Milled Slot

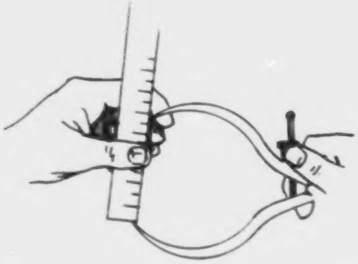


Measuring Shallow Recess

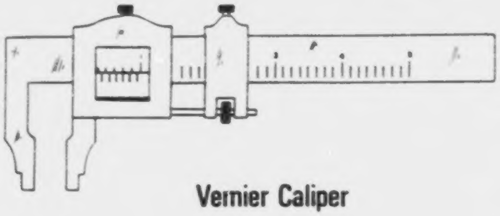
Information Sheet

e. **Calipers** — Used for approximate measurements of external and internal distances

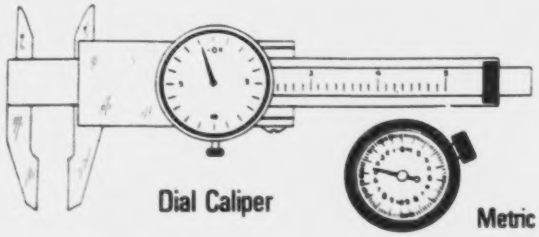

Inside Caliper


Outside Caliper

f. **Vernier calipers** — Used for accurate measurements of external and internal distances


Vernier Caliper

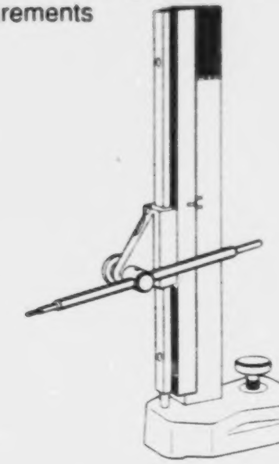
g. **Dial caliper** — Used to obtain a continuous reading and for dial test indicators for gaging


Dial Caliper

Metric Dial

Information Sheet

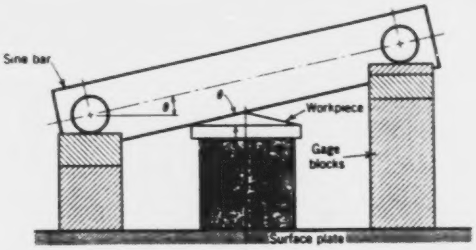
h. **Height transfer gage for surfaces** — Used for accurate parallel surface measurements



Height Transfer
Gage for Surfaces

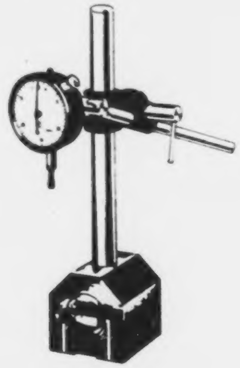
From *Manufacturing Processes* by B.H. Amsbad, P.F. Ostwald, and M.L. Begeman. ©1977. Reprinted by permission of John Wiley and Sons, Inc.

i. **Sine bar** — Used for accurate angle measurements



Sine Bar Setup on Gage Blocks for Measuring an Angle on a Workpiece

j. **Dial indicator gage** — Used to measure alignment, eccentricity, or deviations on surfaces

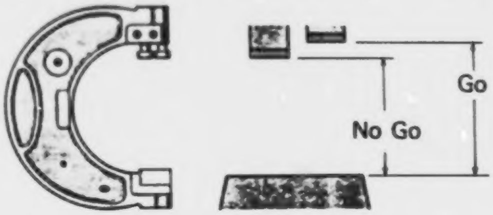


Dial Indicating Gage
with Permanent
Magnet Base

From *Manufacturing Processes* by B.H. Amsbad, P.F. Ostwald, and M.L. Begeman. ©1977. Reprinted by permission of John Wiley and Sons, Inc.

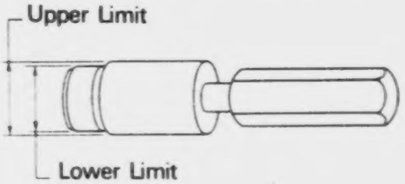
Information Sheet

k. **Snap gage** — Used for plain external dimensions for "go" or "no go" gaging



Adjustable Limit
Snap Gage
Set for Inspecting
a Dimension

l. **Plug gage** — Used for internal dimensions of holes for "go" or "no go" gaging



Plug Gage for
Checking a Hole Size

m. **Divider** -- Used for transferring dimensions and for scribing circles

n. **Optical comparator** — Uses a master or lines on a screen to compare finished parts

Courtesy J&L Metrology Co., Inc.

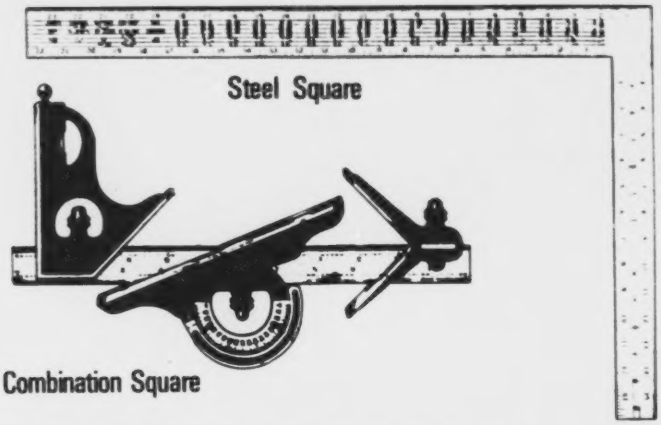
Information Sheet

4. **Welding measuring instruments that drafters need to know.**

   a. Knowing how a product is fabricated helps a drafter better understand the importance of measuring devices and how they are used in the workplace.

   b. Since welding applications are common in mechanical drafting, the tools welders used to measure materials are important tools for the drafter to know.

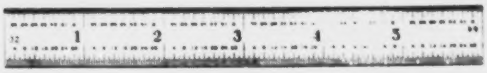
   c. The steel square is not just a square, it is a good rule, and the combination square not only measures angles and bevels, it helps a welder center a pipe.



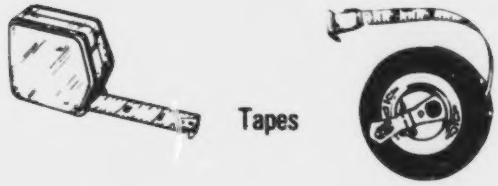
Steel Square

Combination Square

   d. Steel rules used in welding measurement are usually a yard long, hand-held 25-foot retractable tapes are welders favorite tapes, and fabric tapes are used for longer measurements.



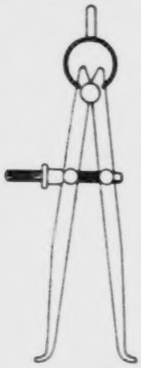
Steel Rule



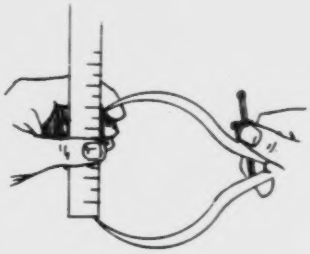
Tapes

Information Sheet

e. Both inside and outside calipers are used by welders to measure everything from plug welds to pipe diameters.



Inside Caliper



Outside Caliper

5. **Basic scales used in mechanical drafting**

   a. The mechanical engineer scale works in an open divided mode for reading fractions, and in a decimal, or full divided mode for reading decimals.

   b. In the fractions or open divided mode, scale ratios are:

      (1) 1″ = 1″ or full size,

      (2) ½″ = 1″ or half size,

      (3) ¼″ = 1″ or quarter size, and

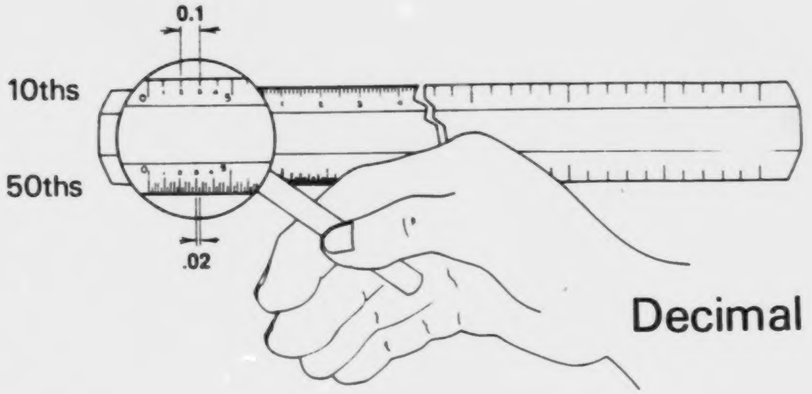
      (4) ⅛″ = 1″ or one-eighth scale.

Information Sheet

c. In the decimal or full divided mode, scale ratios are:

  (1) 10 parts per inch with each division equal to .1"

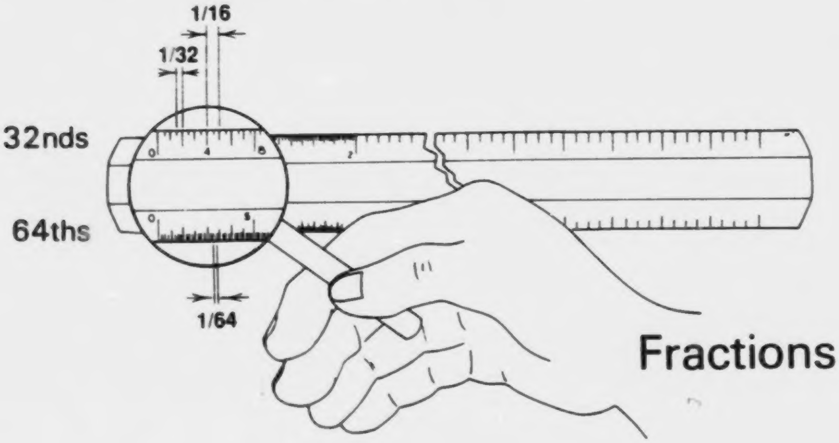
  (2) 50 parts per inch with each division equal to .02"


0.1
10ths
50ths
.02
Decimal

d. A machinists steel rule works in English fractions or English decimals; the fraction scale has two modes:

  (1) 32 parts per inch, or each division equals $\frac{1}{32}$"

  (2) 64 parts per inch, or each division equals $\frac{1}{64}$"

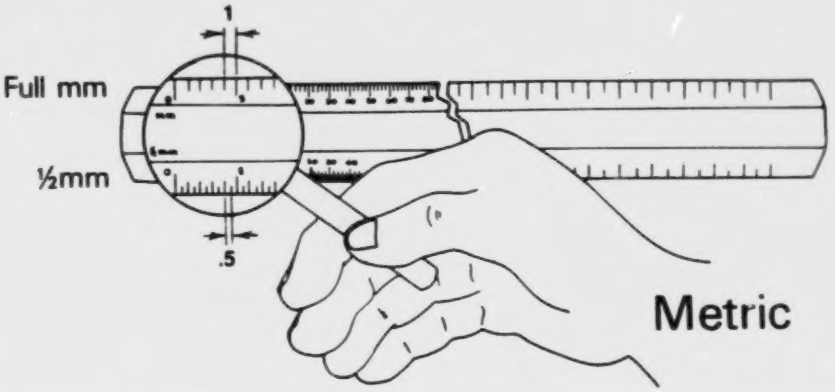

1/16
1/32
32nds
64ths
1/64
Fractions

Information Sheet

6. **Metric scales and their use in mechanical drafting**

   a. Since the millimeter is the primary unit of measurement on a metric scale, the primary metric scale has divisions equal to 1mm (millimeter).

   b. A metric scale may also have division equal to ½ millimeters where each division is equal to .5mm (millimeters).



Note: Secondary metric scales use the meter and the kilometer, but the centimeter and decimeter are rarely used.

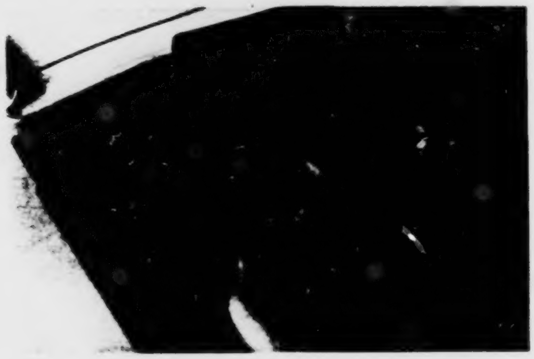
   c. Metric scales come in various ratios, 1:1, 1:2, 1:3, 1:5, and 1:10, and the ratios should be read as 1mm equals 1mm, 1mm equals 5mm, 1mm equals 10mm, etc.

Note: Machinist steel rules may be found with metric scales in combination with decimals and fractions.

Information Sheet

7. Hand-held calculators and their uses in mechanical drafting

a. Because of portability and small size, a hand-held calculator is one piece of equipment a mechanical drafter uses often.



b. The primary functions on a hand-held calculator are the common mathematical functions: add, subtract, multiply, and divide.

c. The secondary functions on a hand-held calculator permit an operator to perform secondary functions which include finding the square of a number, the square root of a number, or finding a reciprocal.

d. Other secondary functions of a hand-held calculator include: logarithms, trigonometric antilogarithm, hyperbolic, angular mode for radians and degrees, and memory storage.

e. Some hand-held calculators also have computer programming capabilities that mirror computer commands for basic programming functions.

f. Some calculators work with an algebraic or business sequence, and others work with a scientific or "Lukasciewicz" sequence.

Information Sheet

g. The hand-held calculator with a scientific sequence will provide a drafter with a better tool for computing complex drafting problems because the base of the scientific sequence is an "order of operations" that provides faster answers.

Note: Calculators with a scientific sequence were once much more expensive than business-sequenced calculators, but the cost of scientific-sequenced calculators is now equal to or less than others, and note in the following example how the number of steps in the business sequence increase with the complexity of the problem.

Problem	Entries Needed	
	Scientific	Business
(3×4) + (7×8)=?	3 ↑ 4 × 7 ↑ 8 × +	3 × 4 + 7 × 8 =
(3+4) × (7+8)=?	3 ↑ 4 + 7 ↑ 8 + ×	3 + 4 = STO 7 + 8 = × RCL =
(3+4) − (7+8)=?	3 ↑ 4 + 7 ↑ 8 + −	3 + 4 = STO 7 + 8 = − RCL x≷y =

Tools and Equipment
Unit 2

Assignment Sheet 1—Read Micrometer Settings in Inches and Millimeters

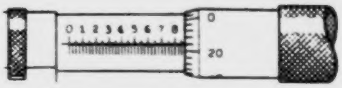
Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Number of correct answers in inches	______
Number of correct answers in millimeters	______

Directions: Be sure to complete Job Sheet 1 before attempting this assignment, then read the micrometer settings that follow and place each answer in the appropriate blank.

Problems

A. Inch



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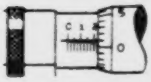

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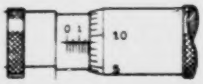

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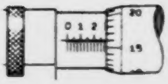

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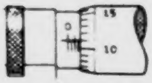

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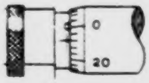

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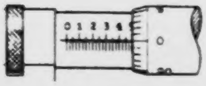

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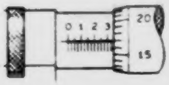
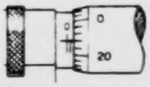


8



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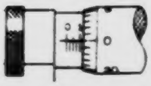

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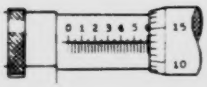

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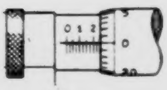

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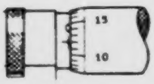


13

Answers

A. 1. ____________

2. ____________

3. ____________

4. ____________

5. ____________

6. ____________

7. ____________

8. ____________

9. ____________

10. ____________

11. ____________

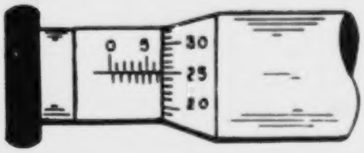
12. ____________

13. ____________

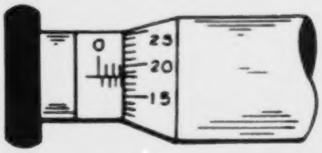
Assignment Sheet 1

Problems

B. Metric



1



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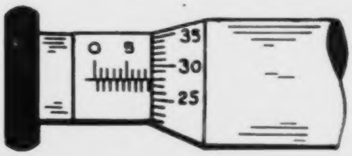

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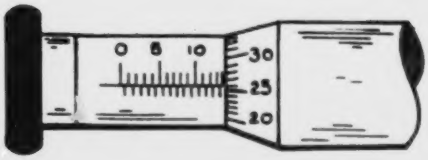
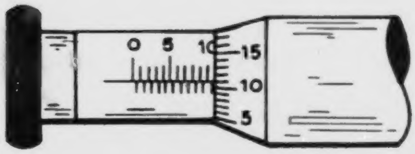

0
5
10
30
25
20

4



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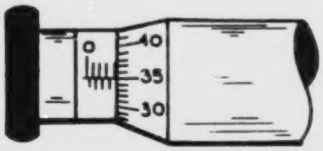


6

Answers

B. 1. ____________

2. ____________

3. ____________

4. ____________

5. ____________

6. ____________

Tools and Equipment
Unit 2

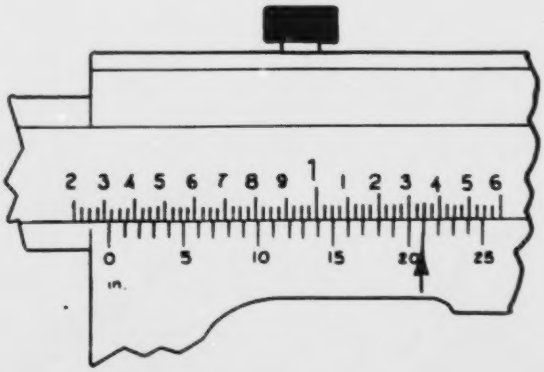
Assignment Sheet 2—Read Vernier Calipers in Inches and Millimeters

Name ______________________ Overall Rating __________

Evaluation criteria	**Rating**
Number of correct answers in inches	______
Number of correct answers in millimeters	______

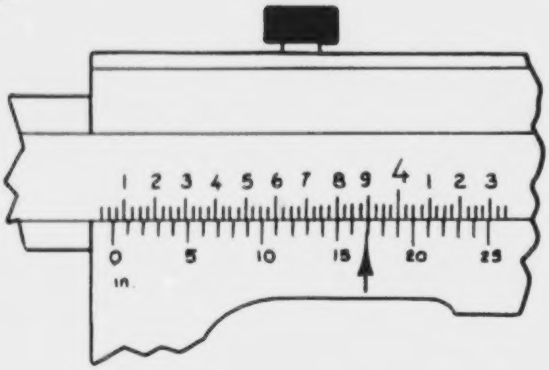
Directions: Be sure to complete Job Sheet 2 before attempting this assignment, then read the vernier settings that follow and place each answer in the appropriate blank.

Problems	**Answers**
A. 25 graduations—inch	
1.	1. ______________



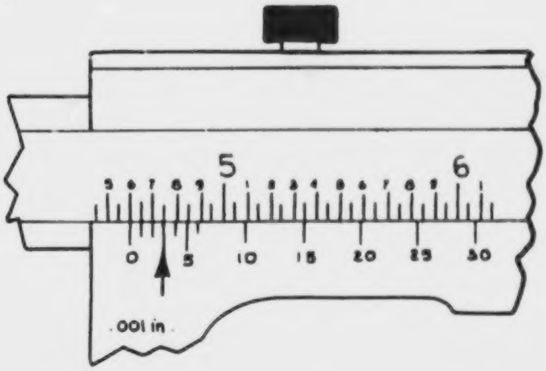
Assignment Sheet 2

Problems	Answers
2.	2. ____________


1
2
3
4
5
6
7
8
9
4
1
2
3
0
5
10
15
20
25
in.

B. 50 graduations—inch

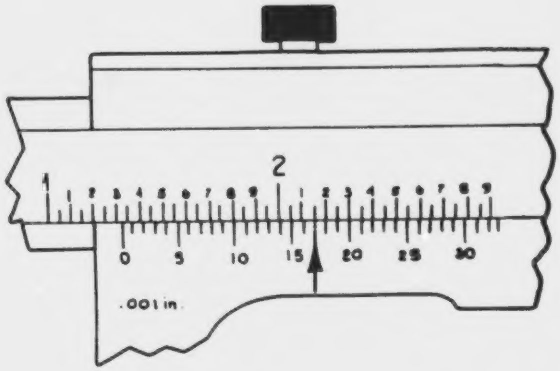
1.	1. ____________


5
6
7
8
9
5
1
2
3
4
5
6
7
8
9
6
1
0
5
10
15
20
25
30
.001 in.

Assignment Sheet 2

2.

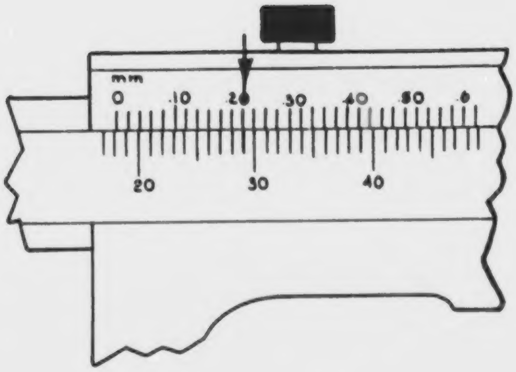
2. ____________________


2
1
1 2 3 4 5 6 7 8 9
1 2 3 4 5 6 7 8 9
0 5 10 15 20 25 30
.001 in.

C. Metric

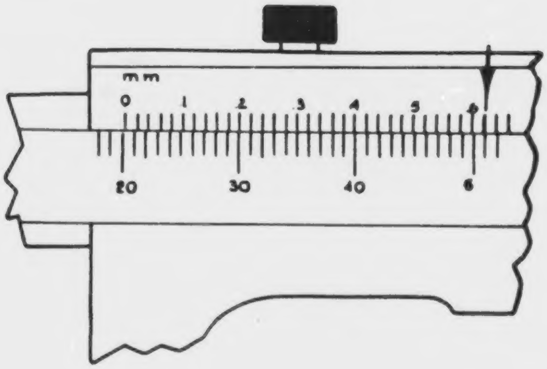
1.

1. ____________________


mm
0 .10 .20 .30 .40 .50 .6
20 30 40

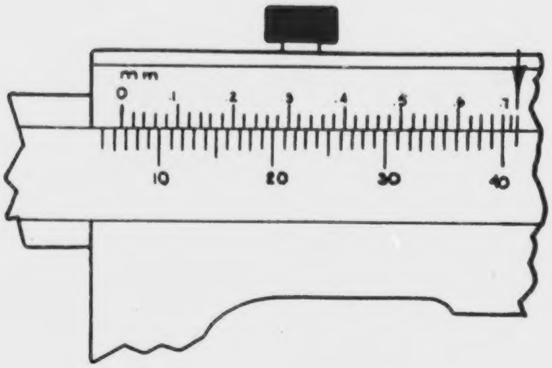
Assignment Sheet 2

2.


mm
0
.1
.2
.3
.4
.5
.6
20
30
40
5

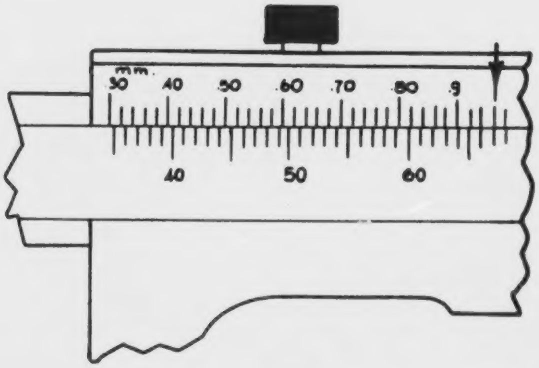
2. ____________________

3.


mm
0
.1
.2
.3
.4
.5
.6
.7
10
20
30
40

3. ____________________

4.


mm.
.30
.40
.50
.60
.70
.80
.9
40
50
60

4. ____________________

Tools and Equipment
Unit 2

Assignment Sheet 3—Measure With Engineer, Machinist, and Metric Scales

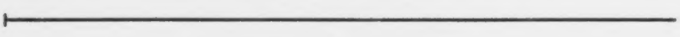
Name ______________________ Overall Rating __________

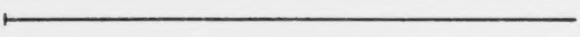
Evaluation criteria	Rating
Number of correct engineer scale measurements	_____
Number of correct machinist scale measurements	_____
Number of correct metric scale measurements	_____

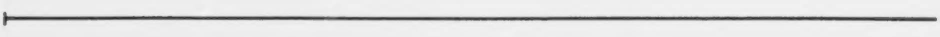
Directions: Measure lines A through H with each of the scales indicated at the top of each column in the following tables. Measure as directed, and place the scale readings in the appropriate spaces in the tables.

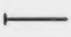
Example: Measure line A with a mechanical engineer scale with inches reading in the 50ths. The reading is 3.89″. Place the 3.98″ under the decimal column of the table for the mechanical engineer scale.

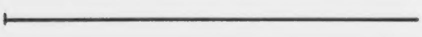
Problems

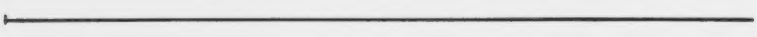
A. 

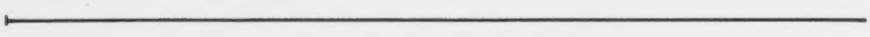
B. 

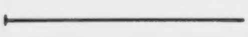
C. 

D. 

E. 

F. 

G. 

H. 

Assignment Sheet 3

	MECHANICAL ENGINEER SCALE			METRIC SCALE (mm) (One place)		
	DECIMAL	FRACTIONS		1:1	1:2	1:5
	1" = 1" (2 Places)	½" = 1" (Nearest 32nd)	¼" = 1" (Nearest 16th)	(One place)	(Nearest mm)	(Nearest mm)
A	3.89					
B						
C						
D						
E						
F						
G						
H						

	MACHINIST STEEL RULE (Full Scale)			
	FRACTIONS (Nearest 1/64)	DECIMAL (Nearest .02)	METRIC (Nearest mm)	METRIC (Nearest ½ mm)
A				
B				
C				
D				
E				
F				
G				
H				

Tools and Equipment
Unit 2

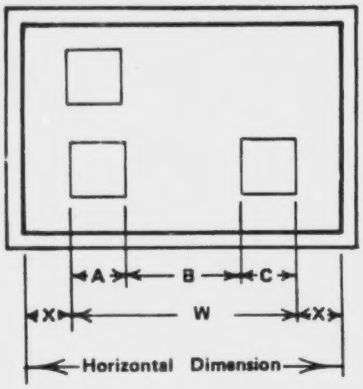
Assignment Sheet 4—Compute Mechanical Drafting Problems With a Hand-Held Calculator

Name ______________________________ Overall Rating __________

Evaluation criteria	Rating
Number of correct layout problems	______
Number of correct triangle calculations	______
Number of correct circle calculations	______
Number of correct rectangle calculations	______

Directions: On engineering grid paper, compute the following mechanical drafting problems using a hand-held calculator with trigonometry functions. Read carefully each example and then complete the problems that follow.

Example A: Make calculations for centering a drawing.



1. Find W.

   A + B + C = W; if A = 60, B = 50, C = 30, then 60 + 50 + 30 = 140mm

2. Find K.

   Horizontal dimension – W = K; if horizontal dimension = 240, then 240 – 140 = 100mm

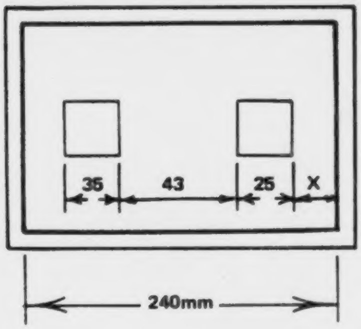
3. Find X.

   K ÷ 2 = X = left and right space; if K = 100, then X = 100 ÷ 2 = 50mm (space on both left and right)

Assignment Sheet 4

Problem A:

1. Find X in the following layout dimensions.

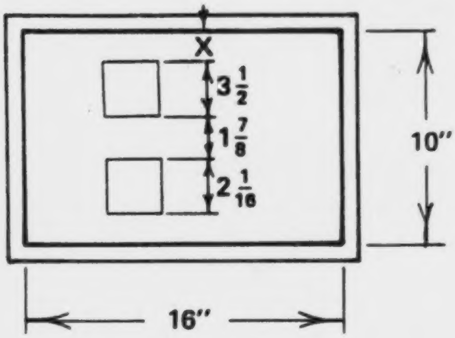

35
43
25
X
240mm

X = ____________

2. Find X in the following layout dimensions.

Note: Convert fractions to decimals by dividing top (numerator) by bottom (denominator).

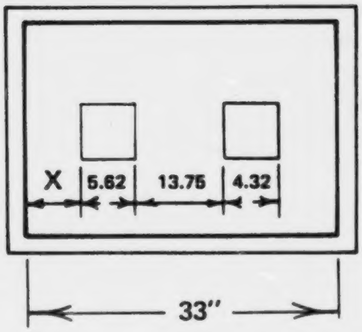
Example: ⅝ = 5 ÷ 8 = .625


X
$3\frac{1}{2}$
$1\frac{7}{8}$
$2\frac{1}{16}$
10"
16"

X = ____________

Assignment Sheet 4

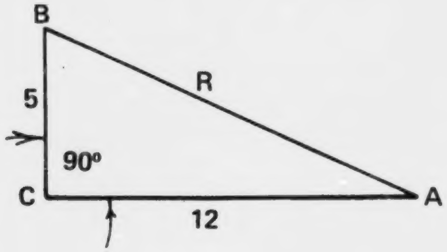
3. Find X in the following layout dimensions.


X
5.62
13.75
4.32
33"

X = ____________

Example B: Make triangle calculations

1. Find R distance using the following steps on the hand calculator:



a. $(AB)^2 = (BC)^2 + (CA)^2$

b. $R^2 = (5)^2 + (12)^2$

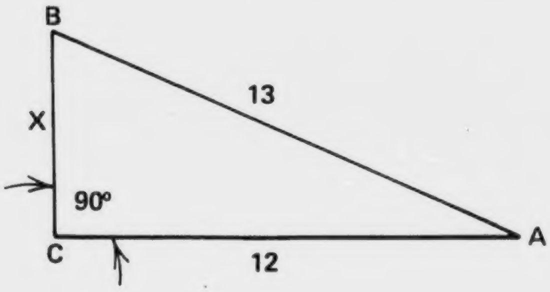
c. $R^2 = 25 + 144$

d. $R^2 = 169$

e. $R = \sqrt{169} = 13$

Assignment Sheet 4

2. Find X distance using the following steps on the hand calculator:



a. $(AB)^2 = (BC)^2 + (CA)^2$

b. $(13)^2 = (BC)^2 + (12)^2$

c. $169 = (BC)^2 + 144$

d. $169 - 144 = (BC)^2$

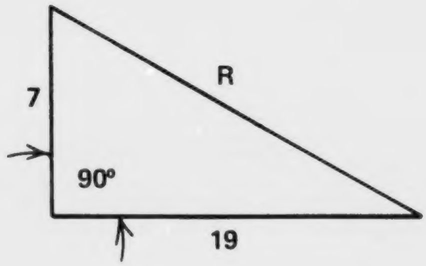
e. $25 = (BC)^2$

f. $\sqrt{25} = BC$

g. $5 = BC = X$

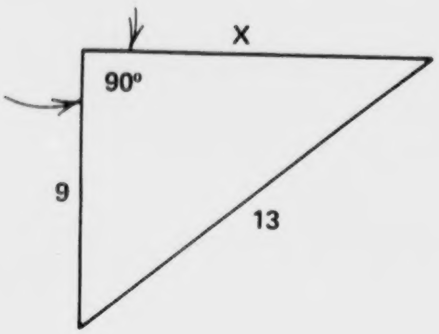
Problem B:

1. Calculate R. R = ____________

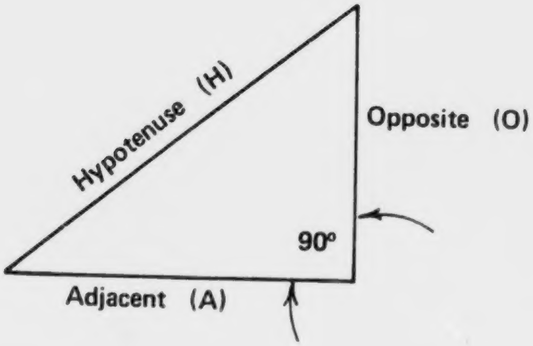


Assignment Sheet 4

2. Calculate X. X = ____________

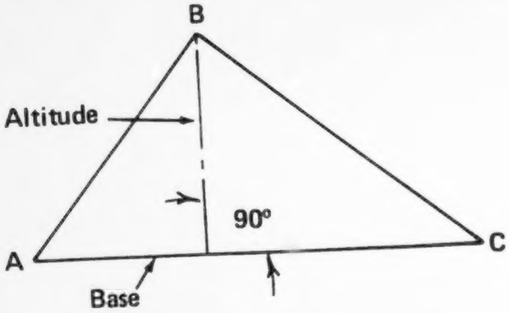


Note: If you should need to find the area for triangles, use the following formula: Area = ½ × Opposite side × Adjacent side.


Hypotenuse (H)
Opposite (O)
90°
Adjacent (A)

Assignment Sheet 4

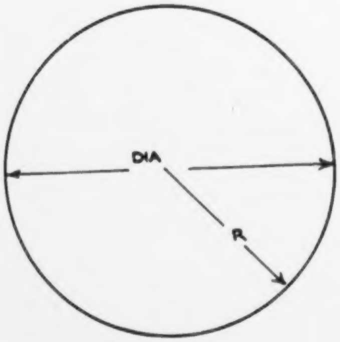
Note: If you should need to find the area of an oblique triangle, use the following formula: Area = $\frac{1}{2}$ × Base × Altitude.



Example C: Make circle calculations by using the following formulas:

$$\text{Area} = \pi R^2 = \frac{\pi(D)^2}{4} \text{ and Circumference} = \pi D = 2\pi R$$

Note: Use 3.1416 = π.



1. Find area:

   a. Use area = πR^2 and radii = 2″.

      Area = 3.1416 $(2)^2$
      = 3.1416 (4)
      = 12.566

      Note: Diameter = 2R.

Assignment Sheet 4

b. Use area = $\frac{\pi(D)^2}{4}$

$$\text{Area} = \frac{3.1416\ (4)^2}{4}$$

$$= 12.566$$

2. Find circumference:

a. Use circumference = $2\pi R$ and radii = 3″.

Circumference = 2 (3.1416) 3
= 18.850

b. Use circumference = πD

Circumference = 3.1416 (6)
= 18.850

Problem C:

1. Calculate area of a 6.32″ diameter circle.

A = ____________

2. Calculate are of a 4.5″ radius circle.

A = ____________

3. Calculate circumference of a 3⅞″ diameter circle.

C = ____________

4. Calculate circumference of a 1.75″ radius circle.

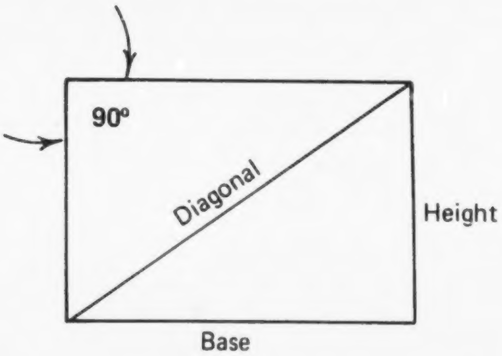
C = ____________

Assignment Sheet 4

Example D: Make rectangle calculations by using the following formulas:

$$\text{Area} = \text{Base} \times \text{Height}; \quad \text{Diagonal} = \sqrt{(\text{Base})^2 + (\text{Height})^2}$$

Note: Diagonal of the rectangle and hypotenuse of the triangle formed are the same.



1. Find area of rectangle:

   a. Base is 4mm and Height is 2mm.

   b. $$\begin{aligned} \text{Area} &= \text{Base} \times \text{Height} \\ &= 4\text{mm} \times 2\text{mm} \\ &= 8\text{mm}^2 \end{aligned}$$

2. Find diagonal of rectangle:

   a. Base is 4mm and Height is 2mm.

   b. $$\begin{aligned} \text{Diagonal} &= \sqrt{(\text{Base})^2 + (\text{Height})^2} \\ &= \sqrt{(4\text{mm})^2 + (2\text{mm})^2} \\ &= \sqrt{16\text{mm}^2 + 4\text{mm}^2} \\ &= \sqrt{20\text{mm}^2} \\ &= 4.4721\text{mm} \end{aligned}$$

Assignment Sheet 4

Problem D:

1. Calculate area of a rectangle 7.75″ × 12.32″.

A = ____________

2. Calculate diagonal of a rectangle 4.59″ × 8.79″.

D = ____________

Tools and Equipment
Unit 2

Job Sheet 1—Measure With a Micrometer

Name ______________________ Attempt Number ________

Date ______________________ Overall Rating ________

Evaluation criteria	Rating
Micrometer preparation	______
Number of workpieces measured correctly	______
Measurement of mounted workpiece	______

A. Tools and materials

Plain micrometers, 0-1.000", 1.000"-2.000"
Workpieces numbered for reference:
  Five new fractional drill bits, assorted
  Five new letter size drill bits, assorted
  Five piece of cold rolled stock, machined parts, or hardened dowels
  One workpiece mounted stationary

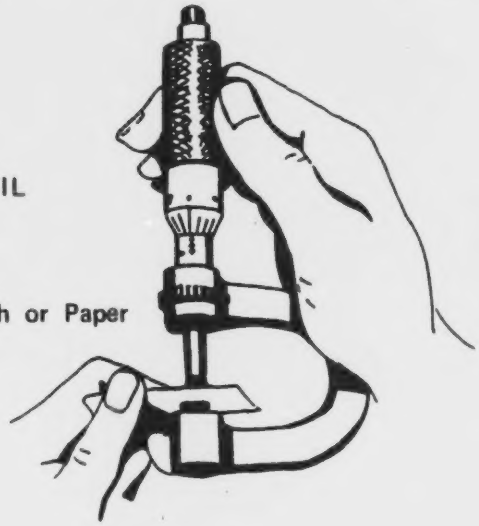
B. Procedure

☐ 1. Clean all workpieces to be measured and make sure they are free of burrs, nicks, or dents.

☐ 2. Number all workpieces for reference.

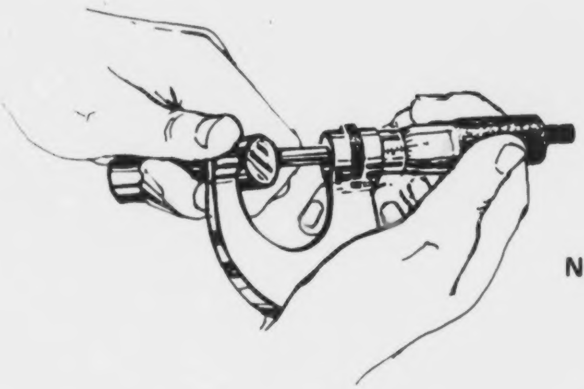
Job Sheet 1

☐ 3. Clean the spindle and anvil of the micrometer.


CLEAN SPINDLE AND ANVIL
Cloth or Paper

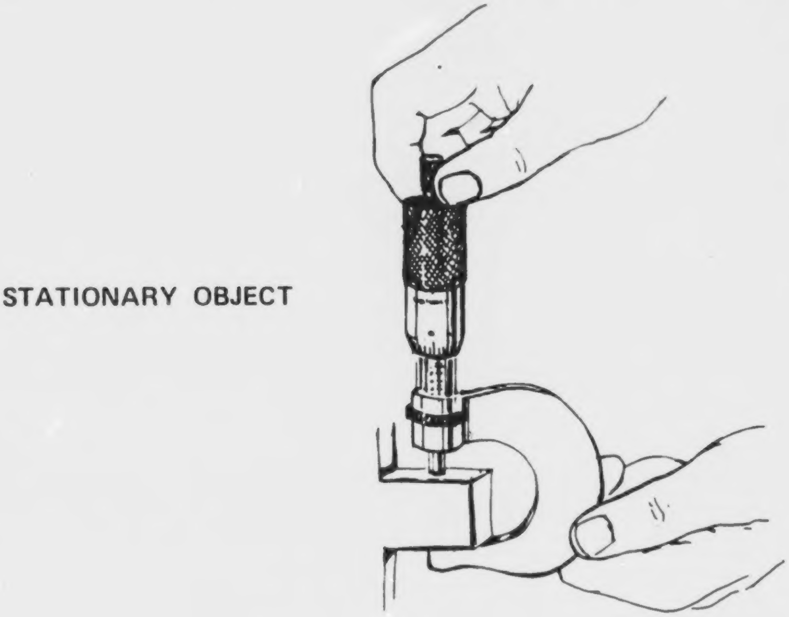
☐ 4. Check the micrometer at zero reference.

☐ 5. Hold the micrometer in the right hand and the workpiece in the left hand to measure non-stationary objects.

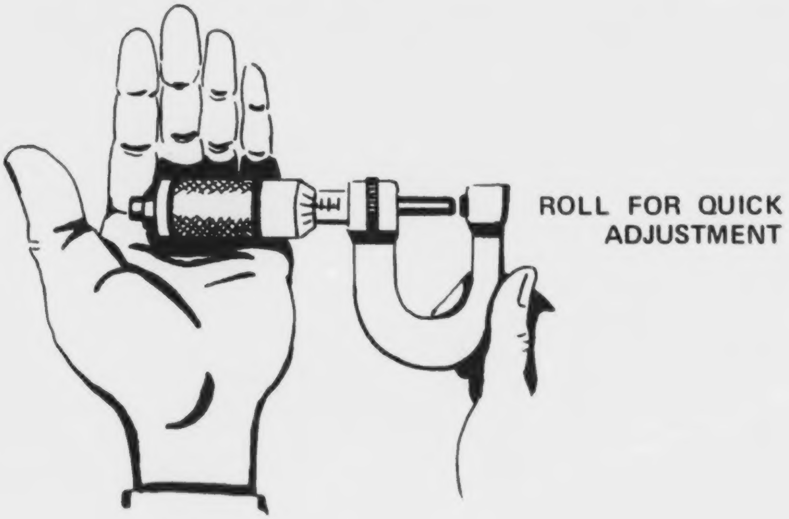

NON-STATIONARY OBJECT

Job Sheet 1

☐ 6. Hold the micrometer in both hands to measure a stationary object.


STATIONARY OBJECT

☐ 7. Roll micrometer along palm of hand or forearm for quick adjustment.


ROLL FOR QUICK
ADJUSTMENT

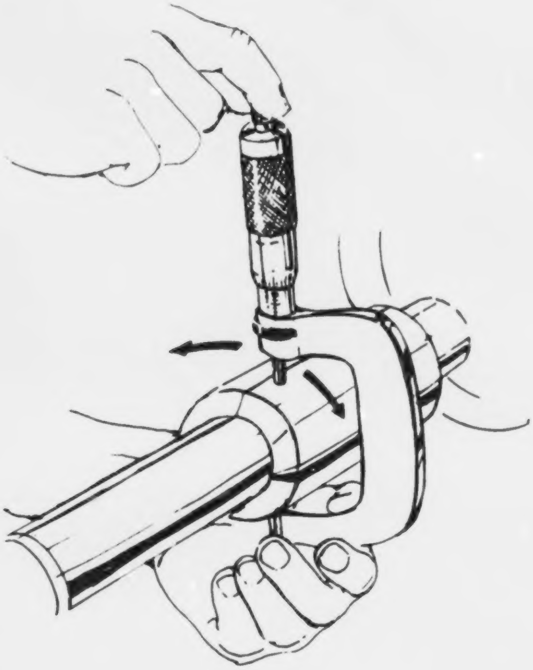
Job Sheet 1

☐ 8. Place the micrometer directly over the center of the workpiece to be measured.

Note: Use proper size micrometer for the job.

☐ 9. Turn the thimble of the micrometer until the anvil and spindle contact the workpiece.

☐ 10. Hold the anvil steady, and move the spindle lightly over the workpiece to locate the true diameter.



WORK BACK AND FORTH
TO FIND TRUE DIAMETER

☐ 11. Use ratchet stop or light sense of touch to determine exact measurement.

☐ 12. Observe micrometer readings.

Note: Lock nut can be turned to hold measurement if micrometer must be removed from workpiece. Spindle must be unlocked before resetting to a new measurement.

Job Sheet 1

☐ 13. List the readings according to the letter or number on the workpiece:

(a) Workpiece #1 ____________________

(b) Workpiece #2 ____________________

(c) Workpiece #3 ____________________

(d) Workpiece #4 ____________________

(e) Workpiece #5 ____________________

(f) Workpiece #6 ____________________

☐ 14. Leave the spindle and anvil of the micrometer open.

☐ 15. Return the micrometer to its correct storage.

☐ 16. Hand in listed readings to the instructor for evaluation.

Evaluator's comments: ____________________

____

____

Tools and Equipment
Unit 2

Job Sheet 2—Measure With a Vernier Caliper

Name ______________________________ Attempt Number ________

Date ______________________________ Overall Rating ________

Evaluation criteria	**Rating**
Caliper preparation	______
Number of workpieces measured correctly	______
Measurement of mounted workpiece	______

A. Tools and materials

Vernier caliper, inch, 25 or 50 divisions, Vernier caliper, metric
Workpieces numbered for reference:
  Assortment of five pieces of cold rolled stock, machined parts, or hardened dowels
  One workpiece mounted stationary

B. Procedure

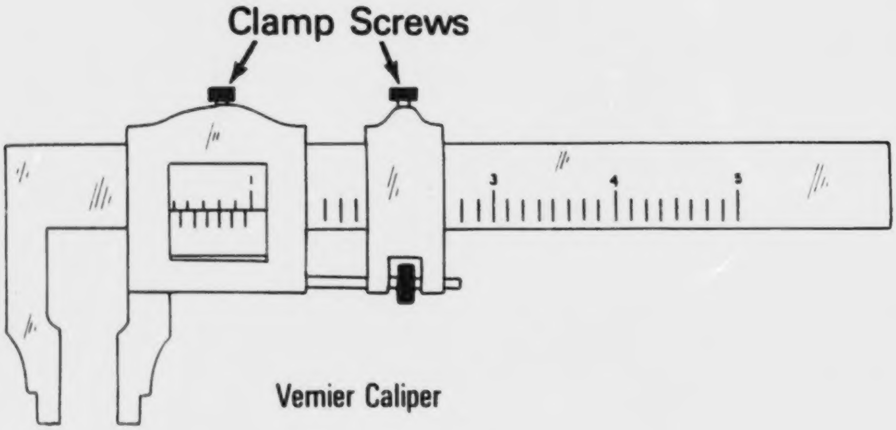
☐ 1. Clean all workpieces to be measured and make sure they are free of burrs, nicks, or dents.

☐ 2. Number all workpieces for reference.

☐ 3. Clean the vernier caliper's jaws.

Job Sheet 2

☐ 4. Slide movable jaws by releasing clamp screws.



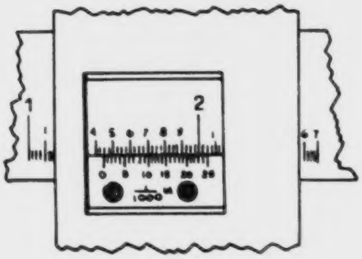
Vernier Caliper

☐ 5. Slide jaws over workpieces to be measured.

Note: Use fine adjustment nut to get a more accurate reading.

☐ 6. Tighten clamp screws with fingers and remove workpiece, or in the case of stationary workpiece, remove caliper.

☐ 7. Read an inch vernier caliper—25 divisions.



☐ 8. Read to the left of the vernier scale zero the last *large* number above the main scale for the number of whole inches.

Example: 1.000″

☐ 9. Read to the left of the vernier scale zero the last *small* number above the main scale for the number in tenths.

Example: 4

Job Sheet 2

☐ 10. Multiply this number by .100.

Example: 4 × .100 = .400

☐ 11. Count the number of graduations from the small number to zero on the vernier scale.

Example: 1

☐ 12. Multiply this number by .025.

Example: 1 × .025 = .025″

☐ 13. Look at the graduations on the vernier scale and the graduations on the bar; find which two graduation lines line up.

☐ 14. Count over from zero to where the two line up.

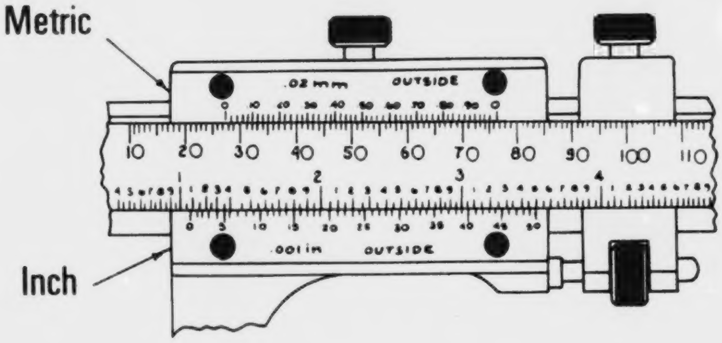
☐ 15. Multiply this number by .011.

Example: 11 × .001 = .011

☐ 16. Add up each part.

Example: 1.000
.400
.025
.011
Answer 1.436″

☐ 17. Read an inch vernier caliper—50 divisions.


Metric
.02 mm
OUTSIDE
0 10 20 30 40 50 60 70 80 90 0
10 20 30 40 50 60 70 80 90 100 110
1 2 3 4
0 5 10 15 20 25 30 35 40 45 50
.001 in
OUTSIDE
Inch

Job Sheet 2

☐ 18. Read to the left of the main inch vernier scale zero the last *large* number above the main inch vernier plate on the bar for the number of whole inches.

Example: 1.000

☐ 19. Read to the left of the vernier scale zero the last *small* number above the main inch vernier plate on the bar for the number in tenths.

Example: 0 × .1 = 000

☐ 20. Count the number of graduations from small number to zero on the vernier scale.

☐ 21. Multiply this number by .050.

Example: 1 × .050 = .050

☐ 22. Look at the graduations on the vernier scale and the graduations on the bar; find which two graduation lines line up.

☐ 23. Count over from zero to where the two line up.

☐ 24. Multiply this number by .001.

Example: 14 × .001 = .014

☐ 25. Add up each part.

Example: 1.000
.000
.050
.014
Answer 1.064"

☐ 26. Read a metric vernier caliper.

☐ 27. Read to the left of the main metric vernier scale zero the number on the bar; the number represents the number of millimeters.

Example: 20mm

Note: The number must be multiplied by 10 to get the number of millimeters.

☐ 28. Read the number of graduation lines from the number to zero.

Job Sheet 2

☐ 29. Multiply this number by 1mm.

Example: 7 × 1 = 7mm

☐ 30. Look at the graduations on the main metric vernier scale and the graduations on the bar; find which two graduation lines line up.

☐ 31. Count over from zero to where the two line up; each graduate is .02.

Example: .42

☐ 32. Add up each part.

Example: 20.mm
7.mm
.42mm
Answer 27.42mm

☐ 33. List the readings for the inch or metric vernier caliper according to the number on the workpiece.

		INCH	METRIC
(a)	Workpiece #1		
(b)	Workpiece #2		
(c)	Workpiece #3		
(d)	Workpiece #4		
(e)	Workpiece #5		
(f)	Stationary workpiece		

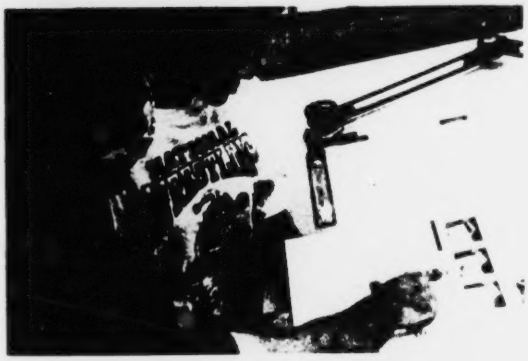
☐ 34. Return calipers to their correct storage.

☐ 35. Hand in listed readings to the instructor for evaluation.

Evaluator's comments: ______________________________

____

____



Reference Materials
Unit 3

Objective Sheet

Unit Objective

After completing this unit, the student should be able to find parts using the *Thomas Register*, request product literature in a letter, and write a brief report using reference materials. The student should demonstrate these competencies by completing the assignment and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to reference materials with their correct definitions.
2. List manufacturing catalogs that contain product information.
3. Complete a list of mechanical drafting standards organizations.
4. Select mechanical drafter and designer handbooks.
5. Name standards found in an ANSI drafting manual.
6. List types of standard parts specified by ANSI.
7. Complete statements about ANSI dimensioning and surface finish standards.
8. Select ANSI small tools and machine elements standards.
9. List type of ANSI metric fastener standards.
10. Complete a list of DOD military standards.
11. Determine manufacturer and mechanical components from the *Thomas Register*. (Assignment Sheet 1)

Objective Sheet

12. Request product literature in a letter. (Assignment Sheet 2)
13. Write a brief, technical report using reference materials. (Assignment Sheet 3)

Reference Materials
Unit 3

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for enrichment of exceptional students as well as accommodation of special needs students.

4. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.

5. Develop teaching plan. Adjust for different learning styles.

6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.

8. Discuss unit and specific objectives.

9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

10. Discuss the assignment and job sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

12. Make copies of the written test. Add or modify test items as needed.

13. Give written test.

Suggested Activities

14. Compile assignment sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignments.

15. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Utilize this entire unit to relate drafting activities not only to standards, but to the general catalog material available from almost all manufacturers. Point out to students the importance of reference materials in finding parts, materials, references to processes, and valuable examples of items that good drafters need to know. Skill areas: **Learning skills, learning to learn**.

2. Make sure you have a copy of the *Thomas Register* available for students to use with Assignment Sheet 1. If you don't have a copy in the classroom, check your community library or the library at a college or university in your area. The *Register* is sometimes available from local industries. Other materials may be substituted for the *Thomas Register*, but if you substitute, make sure the materials reflect the broad scope of availabilities in the *Register*. Skill areas: **Foundation skills, reading**.

3. Help students prepare for Assignment Sheet 2. You may have students who have never written a letter. Invite the business or wordprocessing teacher in your school to help with the project by having a business student type letters required in the assignment sheet. To provide added interest for this activity, have the students bring answers to their letters to class, and examine how manufacturers respond to inquiries about their products. Skill areas: **Foundation skills, writing**.

Resources Used in Developing This Unit

1. *ANSI Catalog-1993*. New York: American National Standards Institute, 1993.

2. *Mac Rae's Blue Book*. Chicago: Mac Rae Publishing Co., 1993.

Suggested Activities

3. Oklahoma Department of Commerce. Debra Lea, Ed. *Oklahoma Directory of Manufacturers and Processors 1992-93*. Norman, OK: University of Oklahoma Printing Services, 1992.

   Note: Your state commerce department or industrial development or similar state agency should publish a directory similar to the one referenced in item 3. Contact your state house for information, or your local Chamber of Commerce.

4. *Thomas Register of American Manufacturers*. New York: Thomas Publishing Company, 1993.

Suggested Supplemental Resources

1. The *ANSI Catalog-1993* is available for $20 from:

   American National Standards Institute
   Attn: Customer Service Department
   11 W. 42nd Street
   New York, NY 10036

   For information, phone (212) 642-4900

2. The *Thomas Register* is available from:

   Customer Service
   The Thomas Publishing Co.
   1 Penn Plaza
   New York, NY 10119

   For information, phone (212) 695-0500. Since the *Register* fills up 26 volumes, its best to call first for information.

Reference Materials
Unit 3

Answers to Assignment Sheets

Assignment Sheets 1, 2, and 3

Evaluate according to criteria written in the assignment sheets.

Reference Materials
Unit 3

Answers to Written Test

1. a. 5
   b. 3
   c. 1
   d. 4
   e. 2

2. a, b, c, d, f

3. Any four of the following in any order:

   a. ANSI, American National Standards Institute
   b. ASME, American Society of Mechanical Engineers
   c. ASTM, American Society for Training and Materials
   d. SAE, Society of Automotive Engineers
   e. ISO, International Standards Organization

4. a. (3)
   b. (2)

5. Any seven of the following in any order:

   a. *Drawing Sheet Size and Format*

   b. *Line Conventions and Lettering*

   c. *Multi and Sectional View Drawings*

   d. *Pictorial Drawings*

   e. *Dimensioning and Tolerancing*

   f. *Screw Thread Representation*

   g. *Gears, Splines, and Serrations*

   h. *Gear and Spline Drawing Standards Part 1*

   i. *Gear and Spline Drawing Standards Part 2*

   j. *Castings and Forgings*

   k. *Forgings*

Answers to Written Test

- l. *Metal Stampings*
- m. *Plastics*
- n. *Mechanical Assemblies*
- o. *Electrical and Electronics*
- p. *Fluid Power Diagrams*
- q. *Engineering Drawings and Related Document Practices Optical Parts 1986*
- r. *Type and Applications of Engineering Drawings*
- s. *Dictionary of Terms for Computer-Aided Preparation of Product Definition Data*
- t. *Chassis Frames*
- u. *Digital Representation for Communication of Product Definition Data (Y14.26M-1989)*
- v. *Parts Lists, Data Lists, and Index Lists*
- w. *Graphical Symbols for Pipe Fittings, Valves, and Piping*

6. Any five of the following in any order:
    - a. Bolts and screws
    - b. Gears
    - c. Keys and pins
    - d. Rivets
    - e. Washers

7. a. *Limits and Fits*
    - b. *Texture*
    - c. *Practice*
    - d. *Limits and Fits*

8. a, b, c, f

9. Any four of the following in any order:
    - a. *Hexagon Socket Head Shoulder Screws Metric*
    - b. *Hex Socket Button Head Cap Screws Metric*
    - c. *Metric Formed Hex Screws*
    - d. *Metric Heavy Hex Bolts*

Answers to Written Test

e. *Metric Heavy Hex Screws*
f. *Metric Heavy Hex Structural Bolts*
g. *Metric Hex Bolt*
h. *Metric Hex Cap Screws*
i. *Metric Hex Lax Screws*
j. *Metric Series Hexagon Keys and Bits*
k. *Metric Series Hexagon Socket Set Screws*
l. *Metric Screw Threads MJ Profile*
m. *Retaining Rings*
n. *Metric Practices Guide for the Welding Industry*
o. *Symbols for Welding, Brazing, and Nondestructive Examination*
p. *Metric Threads*

10. a, b, d

Reference Materials
Unit 3

Written Test

Name ______________________________ Date ________________ Score ____________

1. Match the terms on the right with their correct definitions.

______a. An organization which identifies industrial and public needs for national standards, and coordinates the development and dissemination of those standards

______b. A reference book or manual containing specifications and tables to aid in the drafting and design of manufactured products

______c. A booklet of product literature including specifications of parts, subassemblies, and assemblies of products for consumers and manufacturers to order from or specify on a parts list

______d. A specification, test method, definition, classification, publication, or practice that has been approved by a committee to regulate or control manufacturing

______e. Bolts, screws,nuts, washers, keys, gears, pins, and other hardware specified on a parts list for use on subassemblies or assemblies

1. Product catalog
2. Standard parts
3. Handbook
4. Standard
5. ANSI

2. Select manufacturing catalogs that contain product information literature. Place an "X" beside each entry that contains product information literature.

______a. *Materials Selector Issue*

______b. *Thomas Register*

______c. *Mac Rae's Blue Book*

______d. *Dictionary of Manufacturers*

______e. *Dictionary of Tools and Machines*

______f. *Sweet's Catalog File*

Written Test

3. List and define the acronyms of four mechanical drafting standards organizations.

   a. ______ ____

   b. ______ ____

   c. ______ ____

   d. ______ ____

4. Solve problems about mechanical drafter and designer handbooks. Select the number of the statements that best solves each of the following problems.

   a. Your instructor has assigned you the task of looking up material that will be needed in notes defining a process. To save time, you should:

      (1) Look first in the *Gear Handbook*.

      (2) Look first in *Machiner's Handbook*.

      (3) Look first in *Chambers Technical Dictionary*.

   b. Your instructor has assigned you the task of looking up material needed for notes that will accompany a design for an engine support in an automobile. To save time, you should:

      (1) Look first in the *ASME Handbook*.

      (2) Look first in *SAE Automotive Drafting Standards*.

      (3) Look first in *Automotive Production Guidebook*.

5. List seven standards found in an ANSI drafting manual. Phrase your answers to approximate materials from Objective 5 in the Information Sheet of this unit.

   a. ____

   b. ____

   c. ____

   d. ____

   e. ____

   f. ____

   g. ____

Written Test

6. List five standard parts specified by ANSI. Phrase your answers in general terms like those in Objective 6 of the Information Sheet in this unit.

   a. ________________________________

   b. ________________________________

   c. ________________________________

   d. ________________________________

   e. ________________________________

7. Complete a list of ANSI dimensioning and surface finish standards. Circle the material that best completes each of the following entries.

   a. *Preferred (Machining) (Limits and Fits) for Cylindrical Parts*

   b. *Surface (Preparation) (Texture)*

   c. *Metric (Nuts and Bolts) (Practice)*

   d. *Preferred Metric (Machining) (Limits and Fits)*

8. Select ANSI small tools and machine element standards. Place an "X" beside items that appear in the standard.

   ______a. *Jig Bushings*

   ______b. *Machine Tapers*

   ______c. *Milling Cutters and End Mills*

   ______d. *Hex Screws*

   ______e. *T-Bars*

   ______f. *Twists, Drills, Straight Shank, and Taper Shanks*

Written Test

9. List four ANSI metric fasteners standards. Phrase your answers to approximate those in Objective 9 of this unit.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

10. Select DOD military standards. Place an "X" beside each entry that is a military standard.

______a. *Architectural Symbols*

______b. *Welded Joint Design*

______c. *Electricity and Electricity Reference Designations*

______d. *Printed Wiring and Printed Circuits*

***Permission to duplicate this test is granted.**

Reference Materials
Unit 3

Unit Evaluation Form

Student Name ______________________ Unit Rating ________

Assignment Sheet 1—Use the *Thomas Register* to Determine the Manufacturer of Mechanical Components Rating ______

Comments: ______________________

____

Assignment Sheet 2—Write a Letter Requesting Product Literature for Mechanical Components Rating ______

Comments: ______________________

____

Assignment Sheet 3—Write a Technical Report Using Reference Materials Rating ______

Comments: ______________________

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ______________________

____

Teacher Signature ______________________ Date ________

Student Signature ______________________ Date ________

***Permission to duplicate this form is granted.**

Reference Materials
Unit 3

Information Sheet

1. **Terms and definitions**

   a. **ANSI (American National Standards Institute)** — An organization which identifies industrial and public needs for national standards, and coordinates the development and dissemination of those standards

   b. **Handbook** — A reference book or manual containing specifications and tables to aid in the drafting and design of manufactured products

   c. **Product catalog** — A booklet of product literature including specifications of parts, subassemblies, and assemblies of products for consumers and manufacturers to order from or specify on a parts list

   d. **Standard** — A specification, test method, definition, classification, publication, or practice that has been approved by a committee to regulate or control manufacturing

   e. **Standard parts** — Bolts, screws, nuts, washers, keys, gears, pins, and other hardware specified on a parts list for use on subassemblies or assemblies

2. **Manufacturing catalogs that contain product information literature**

   a. *Materials Selector Issue* — This catalog contains materials used in design engineering.

   b. *Thomas Register* — This catalog contains products and service information.

   c. *Mac Rae's Blue Book* — This catalog selects products and classifies them.

   d. *Directory of Manufacturers* — This catalog is available in individual states, usually from the state department of commerce or industrial development department.

   e. *Sweet's Catalog File* — This catalog presents several catalogs available in manufacturing and architecture.

Information Sheet

3. Mechanical drafting standards organizations

a. ANSI (American National Standards Institute)

b. ASME (American Society of Mechanical Engineers)

c. ASTM (American Society of Training and Materials)

d. SAE (Society of Automotive Engineers)

e. ISO (International Standards Organization)

Information Sheet

4. **Mechanical drafter and designer handbooks**
   - a. *American Machinist's Handbook*
   - b. *ASME Handbook*
   - c. *Chambers Technical Dictionary*
   - d. *Databook for Human Factors Engineering*
   - e. *Gear Handbook*
   - f. *The Human Body in Equipment Design*
   - g. *Human Engineering Guide to Equipment Design*
   - h. *Machinery's Handbook*
   - i. *Production Notebook*
   - j. *SAE Automotive Drafting Standards*
   - k. *SAE Handbook*
   - l. *Standard Handbook for Mechanical Engineers*
   - m. *SME Tool and Manufacturer's Engineer's Handbook*
   - n. *Welding Handbook*
   - o. *AISC Steel Construction Manual*
5. **Standards found in an ANSI drafting manual**
   - a. *Drawing Sheet Size and Format (Y14.1-1980)*
   - b. *Line conventions and Lettering (Y14.2M-1991)*
   - c. *Multi and Sectional View Drawings (Y14.3-1975)*
   - d. *Pictorial Drawings (Y14.4M-1982)*
   - e. *Dimensioning and Tolerancing (Y14.5M-1982)*
   - f. *Screw Thread Representation (Y14.6-1978)*
   - g. Gears, Splines, and Serrations (Y14.7-1978)

Information Sheet

h. *Gear and Spline Drawing Standards Part 1 (Y14.7.1-1971)*

i. *Gear and Spline Drawing Standards Part 2 (Y14.7.2-1978)*

j. *Castings and Forgings (Y14.8M-1989)*

k. *Forgings (Y14.9-1958)*

l. *Metal Stampings (Y14.10-1959)*

m. *Plastics (Y14.11-1958)*

n. *Mechanical Assemblies (Y14.14-1961)*

o. *Electrical and Electronics (Y14.15-1966)*

p. *Fluid Power Diagrams (Y14.17-1966)*

q. *Engineering Drawings and Related Document Practices Optical Parts (Y14.18M-1986)*

r. *Type and Applications of Engineering Drawings (Y14.24.M-1989)*

s. *Dictionary of Terms for Computer-Aided Preparation of Product Definition Data (Y14.26.3-1975)*

t. *Chassis Frames (Y14.32.1-1974)*

u. *Digital Representation for Communication of Product Definition Data (Y14.26M-1989)*

v. *Parts Lists, Data Lists, and Index Lists (Y14.24M-1988)*

w. *Graphical Symbols for Pipe Fittings, Valves, and Piping (Y32.2.3-1949)*

Note: Another common standard is *Abbreviations (Y1.1-1989)*, but this is not commonly found in a manual of drafting standards.

6. **Standard parts specified by ANSI**

a. Bolts and screws:

(1) *Hexagon or Slotted Head Cap Screws, Square Head or Slotted Set Screws (B18.6.2-1972)*

(2) *Plow Bolts (B18.9-1958, R1971)*

Information Sheet

- (3) *Round Head Bolts (B18.5-1971)*
- (4) *Slotted and Recessed Head Machine Screws and Machine Screw Nuts (B18.6.3-1972)*
- (5) *Socket Cap, Shoulder, and Set Screws (B18.3-1976)*
- (6) *Square and Hex Bolts and Screws (B18.2.1-1972)*
- (7) *Square and Hex Nuts (B18.2.2-1987)*
- (8) *Track Bolts and Nuts (B18.10-1982)*

b. Gears:

- (1) *Gear Drawing Standards Part 1 (Y14.7.1-1971)*
- (2) *Gear Drawing Standards Part 2 (Y14.7.2-1978)*
- (3) *Basic Gear Geometry (AGMA 115.01-1989)*
- (4) *Gear Nomenclature (AGMA 1012-F90)*

c. Keys and pins:

- (1) *Machine pins (B5.20-1958)*
- (2) *Keys and Keyseats (B17.1-1967)*
- (3) *Woodruff Keys and Keyseats (B17.2-1967)*

d. Rivets:

- (1) *Large Rivets (B18.1.2-1972)*
- (2) *Small Solid Rivets (B18.1.1-1972)*

e. Washers:

- (1) *Lock Washers (B18.21.1-1990)*
- (2) *Plain Washers (B18.22.2-1981)*

Information Sheet

7. **ANSI dimensioning and surface finish standards**
    a. *Preferred Limits and Fits for Cylindrical Parts (B4.1-1987)*
    b. *Surface Texture (B46.1-1985)*
    c. *Metric Practice (IEEE 268-1992)*
    d. *Tolerance for Metric Dimensional Products, General (B4.3-1978)*
    e. *General Tolerances for Metric Dimensioned Products (B4.3-1978)*
    f. *Preferred Metric Limits and Fits (B4.2-1978)*
8. **ANSI small tools and machine elements standards**
    a. *Jig Bushings (B94.33-1974)*
    b. *Machine Tapers (B5.10-1981)*
    c. *Milling Cutters and End Mills (B94.19-1985)*
    d. *Reamers (B94.2-1983)*
    e. *T-Slots (B5.1M-1985)*
    f. *Taps, Cut and Ground Threads (B94.9-1987)*
    g. *Twist, Drills, Straight Shank, and Taper Shanks (B94.11M-1979)*
9. **ANSI metric fasteners standards**
    a. *Hexagon Socket Head Shoulder Screws metric (B18.3.3M-1986)*
    b. *Hex Socket Button Head Cap Screws Metric (B18.3.4M-1986)*
    c. *Metric Formed hex Screws (B18.2.3.2M-1979)*
    d. *Metric Heavy Hex Bolts (B18.2.3.6M-1979)*
    e. *Metric heavy Hex Screws (B18.2.3.3M-1979)*
    f. *Metric Heavy Hex Structural Bolts (B18.2.3.7M-1979)*
    g. *Metric hex Bolt (B18.2.3.5M-1979)*
    h. *Metric Hex Cap Screws (B18.2.3.1M-1989)*

Information Sheet

- i. *Metric Hex Lax Screws (B18.2.3.8M-1981)*
- j. *Metric Series Hexagon Keys and Bits (B18.3.2M-1979)*
- k. *Metric Series Hexagon Socket Set Screws (B18.3.6M-1986)*
- l. *Metric Screw Threads MJ Profile (B1.21M-1978)*
- m. *Retaining Rings (B27.8M-1978)*
- n. *Metric Practices Guide for the Welding Industry (A1.1-1989)*
- o. *Symbols for Welding, Brazing, and Nondestructive Examination (A2.4-91)*
- p. *Metric Threads (ISO 68)*

10. **DOD (Department of Defense) Military Standards**

- a. *Screw Thread Conventions and Methods of Specifying (MIL. STD-9A)*
- b. *Abbreviations for Use on Drawings (MIL. STD-12C)*
- c. *Architectural Symbols (MIL. STD-14C)*
- d. *Electrical and Electronic Reference Designations (MIL. STD-16C)*
- e. *Part 1 Mechanical Symbols (MIL. STD-17B)*
- f. *Part No. 2 Change 1 Mechanical Symbols for Aeronautical, Aerospace-craft, and Spacecraft Use (MIL. STD-17B)*
- g. *Structural Symbols (MIL. STD-18B)*
- h. *Welded Joint Design (MIL. STD-22A)*
- i. *Thread Standards (MIL. STD-8879)*
- j. *Engineering Drawing Practices (MIL. STD-100A)*
- k. *Printed Wiring Boards (MIL. STD-P5510)*
- l. *Aeronautic Taper Pipe Threads (MIL. STD-P7105)*
- m. *Printed Wiring for Electronic Equipment (MIL. STD-275D)*
- n. *Printed Wiring and Printed Circuits - Terms and Definitions (MIL. STD-429)*

Reference Materials
Unit 3

Assignment Sheet 1—Use the *Thomas Register* to Determine the Manufacturer of Mechanical Components

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Number of items researched	______
Number of items properly presented	______
Neatness and appearance	______

Directions: Use the *Thomas Register* to locate at least one manufacturer's name and address for each of the following products/parts.

A. Electric Motor

B. Machine screws

C. Cams

D. Spring lock washer

E. Gears

F. Solar collector

G. Shear for sheet metal

H. Pump

Reference Materials
Unit 3

Assignment Sheet 2—Write a Letter Requesting Product Literature for Mechanical Components

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Completeness of rough copy of letter	______
Neatness and appearance of finished letter	______
Clarity of response to letter	______

Directions: Select one of the addresses from Assignment Sheets 1 or select a name from the *Thomas Register*. Write a short letter to the manufacturer requesting information about product specifications and costs. Have your instructor approve your rough copy, and then neatly type your letter and mail it. In the following sample letter, the items in italics indicate where you should fill in information you are requesting.

Turn this page over for the example

Assignment Sheet 2

425 Elm Street
Hometown, OK 74074

October 25, 1994

Sales Department
Inerpac Corporation
101 Industrial Highway
Butler, WI 53071

Sales Representative:

I am a drafting student at Central AVTS and am in the process of designing equipment. Please send me product literature, specifications, and costs for *Hi-Tonnage Jacking Cylinders*. The information would assist in helping me complete an assignment, and teach me to appreciate the value of good reference materials.

Thank you for your consideration.

Sincerely yours,

Janey Winslow

Reference Materials
Unit 3

Assignment Sheet 3—Write a Technical Report Using Reference Materials

Name ______________________ Overall Rating __________

Evaluation criteria	**Rating**
Quality of material presented	______
References accompanying report	______
Neatness and appearance	______

Directions: Write a short, technical report in an area which interests you. Pick a specific as opposed to a general area to make your work easier. Use available indexes to find appropriate reference materials. Limit your report to about three hand-written pages or about two double-spaced typewritten pages. Use the following guidelines to prepare your report.

1. Title page (subject, your name, date)
2. Introduction (what your paper will cover, why you chose this area)
3. Body (logical presentation of information discovered while researching)
4. Conclusion (brief summary of what you have learned, final remarks)
5. References (at least three)

   Note: Books are categorized in the library according to the author, title, and subject in the card catalogs. Two good indexes to find articles in the library are *Engineering Index* and *Applied Science and Technology Index*.

Dimensioning and Tolerancing
Unit 4

Objective Sheet

Unit Objective

After completing this unit, the student should be able to illustrate dimensioning tolerances to include surface quality, position, and geometric form dimensions. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to dimensioning and tolerancing with their correct definitions.
2. Select size dimensions for given geometric shapes.
3. Select true statements about location dimensions for geometric shapes.
4. Select mating dimensions in an assembly drawing.
5. Select true statements about basic guidelines for numerical control dimensioning.
6. Select fits for inch units and their applications.
7. Select fits for metric units and their applications.
8. Calucalate the limits for clearance fit in inch units using the basic hole system.
9. Calculate the limits for locational fit in inch units using the basic hole system.
10. Calculate the limits for force fit in inch units using the basic hole system.
11. Calculate the limits for clearance fit in inch units using the basic shaft size system.
12. Calculate the limits for clearance fit in metric units using the basic hole system.

Objective Sheet

13. Calculate the limits for transition fit in metric units using the basic hole system.
14. Calculate the limits for interference fit in metric units using the basic hole system.
15. Determine tolerance ranges and their relationship to costs and shop processes.
16. Select true statements about guidelines for determining clearance fit on standard dowels.
17. Select true statements about guidelines for determining interferance fit on standard dowels.
18. Select true statements about guidelines for determining limit dimensions for the interchangability of parts.
19. Arrange in order the steps for determining limit dimensions for intermediate parts to retain overall limits.
20. Complete a chart of ANSI and ISO symbols for tolerances of position and form.
21. Match ANSI modifying symbols for tolerances of position and form with their terms.
22. Identify position and form symbols in a drawing.
23. Complete statements about descriptions of position and form.
24. Select true statements about positional tolerancing.
25. Differentiate between features of MMC and RFS.
26. Select true statements about angular tolerances.
27. Differentiate between correct and incorrect placement of surface quality symbols.
28. Select true statements about surface quality notes.
29. Match lay symbols with their meanings.
30. Evaluate production processes and the degrees of roughness they produce.
31. Select recommended values for surface quality roughness.
32. Select true statements about the advantages of using CAD for dimensioning and tolerancing.
33. Dimension an object completely. (Assignment Sheet 1)

Objective Sheet

34. Calculate and dimension clearance fit tolerances using standard fit tables. (Assignment Sheet 2)

35. Calculate and dimension interference fit tolerances using standard fit tables. (Assignment Sheet 3)

36. Calculate and assign tolerances to mating parts using standard fit tables. (Assignment Sheet 4)

37. Calculate and dimension hole-size limits for standard dowels. (Assignment Sheet 5)

38. Dimension an object using position and form tolerances. (Assignment Sheet 6)

39. Determine ranges of motion of limbs and spaces required for a person. (Assignment Sheet 7)

Dimensioning and Tolerancing
Unit 4

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for enrichment of exceptional students as well as accommodation of special needs students.

4. Make transparencies from the transparency masters included with this unit. These appear in the teacher edition only and are designed to be used with the following objectives:

   TM 1—Tolerancing Terms, with 1A and 1B Overlays (Objective 1)
   TM 2—Graphical Representation of Tolerance Zones (Objective 1)
   TM 3—Metric Tolerance Designation (Objective 1)
   TM 4—Form and Proportion of Geometric Tolerancing Symbols (Objective 2)
   TM 5—Form and Proportion of Dimensioning Symbols (Objective 3)
   TM 6—Lay Symbols (Objective 29)

5. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.

6. Develop teaching plan. Adjust for different learning styles.

7. Make copies of Unit Evaluation Form.

Delivery and Application

8. Provide students with unit of instruction.

9. Discuss unit and specific objectives.

10. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

11. Discuss the assignment and job sheets. Review criteria for evaluation of these activities.

Suggested Activities

Evaluation

12. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

13. Make copies of the written test. Add or modify test items as needed.

14. Give written test.

15. Compile assignment sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignments.

16. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Impress students with the importance of dimensioning and tolerancing in mechanical drafting and the world of manufacturing. Use TM 1 and its overlays along with TMs 2, 3, and 4 to demonstrate the concept of dimensioning and tolerancing. Reinforce these early objectives with materials from a local or area industry so students can see dimensioning and tolerancing as it is employed in the workplace. Skill areas: **Communication skills, listening**.

2. Use Objective 4 to talk about the elements of engineering that are necessary to be a good drafter. Talk to the students about manufacturing conventions used in industry to such a degree that they literally become a part of the drafting world too. Impress upon students the bonds that tie mechanical drafting and industry together.. Skill areas: **Foundation skills, science**.

3. Repeat often the need for students to develop a good foundation in dimensioning and tolerancing as you teach the objectives that treat the various fit dimensions. Take time to demonstrate the principles of clearance, location, and force fit, so students will be able to handle the assignment sheets with confidence.. Skill areas: **Foundation skills, science, and math**.

4. Use transparencies 4 and 5 to good advantage as you teach materials about position and form dimensioning. Have samples available to show students how these items come into play in working prints in industry. Skill area: **Foundation skills, science, and math.**

Suggested Activities

Resources Used in Developing This Unit

1. American National Standards Institute. *Dimensioning and Tolerancing (ANSI Y.14.5-1982).* New York: American Society of Mechanical Engineers, 1982.
2. Dreyfus, Henry. *The Measure of Man and Woman: Human Factors in Design.* New York: Whitney Library of Design, 1993.
3. Foster, Lowell W. *Geo-Metrics.* Reading, MA: Addison-Wesley, 1986.
4. Giesecke, Frederick E., Et al *Technical Drawing.* New York: Macmillan Publishing Co., Inc., 1993.
5. Jensen, Cecil. *Geometric Dimensioning and Tolerancing For Engineering & Manufacturing Technology.* Albany, NY: Delmar Publishers, Inc., 1993.

Suggested Supplemental Resources

1. All programs need a copy of *Dimensioning and Tolerancing ANSI Y14.5M-1982.* This is the American National Standard for engineering drawings and related documentation practices. The regular cost of the manual is $39.00, but it is available from ASME with a 20% educational discount. The 145-page manual is well worth its cost. For information write:

   ASME
   22 Law Drive
   P.O. Box 2300
   Fairfield, NJ 07007-2300

   or phone: 1-800-843-2763

2. *Mannequin Designer* is a software program that enables CAD drafters to draw detailed human models into their designs and presentations. It has extended features and 3-D capabilities, including a 3-D furniture library. For an evaluation copy, phone 1-800-437-4441 or write to:

   HumanCad
   1800 Walt Whitman Road
   Melville, NY 11747

Dimensioning and Tolerancing
Unit 4

Answers to Assignment Sheets

Assignment Sheet 1

Evaluate according to criteria written in the assignment sheet.

Assignment Sheet 2

A. $\frac{.9992}{.9984}$ $\frac{2.4996}{2.4991}$

$\frac{1.0008}{1.0000}$ $\frac{2.5007}{2.5000}$

B. $\frac{39.991}{39.975}$ $\frac{2.500}{2.475}$

$\frac{40.025}{40.000}$ $\frac{2.545}{2.520}$

Assignment Sheet 3

A. $\frac{3.0047}{3.0040}$ $\frac{.5011}{.5007}$

$\frac{3.0012}{3.0000}$ $\frac{.5007}{.5000}$

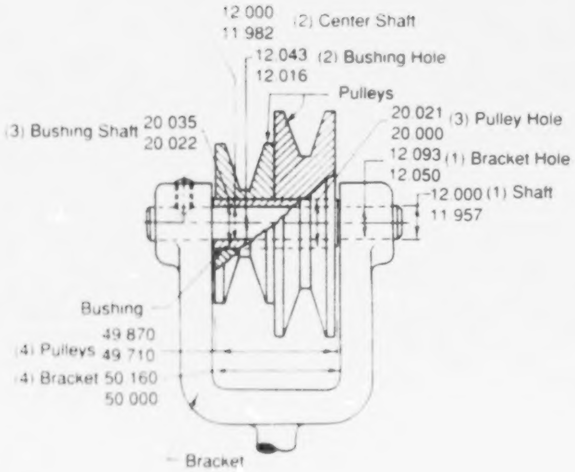
B. $\frac{10.000}{9.991}$ $\frac{1.200}{1.194}$

$\frac{9.978}{9.963}$ $\frac{1.194}{1.184}$

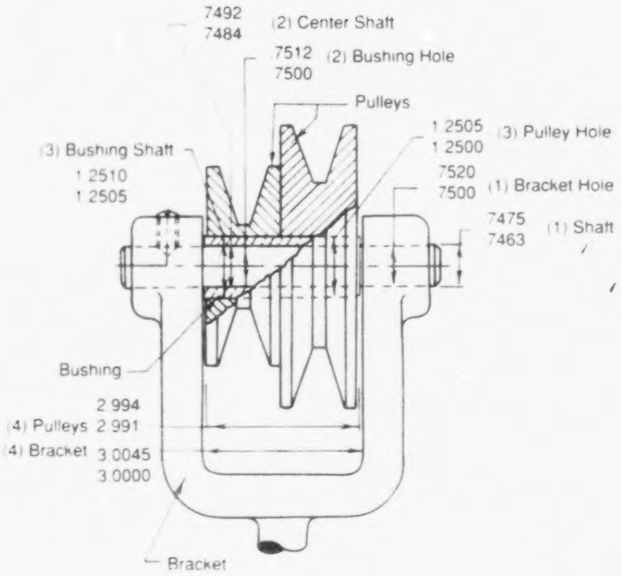
Answers to Assignment Sheets

Assignment Sheet 4

A. Metric system


12 000
11 982 (2) Center Shaft
12 043 (2) Bushing Hole
12 016
Pulleys
(3) Bushing Shaft 20 035
20 022
20 021 (3) Pulley Hole
20 000
12 093 (1) Bracket Hole
12 050
12 000 (1) Shaft
11 957
Bushing
49 870
(4) Pulleys 49 710
(4) Bracket 50 160
50 000
Bracket

B. Inch system


7492
7484 (2) Center Shaft
7512 (2) Bushing Hole
7500
Pulleys
(3) Bushing Shaft
1 2510
1 2505
1 2505 (3) Pulley Hole
1 2500
7520
7500 (1) Bracket Hole
7475
7463 (1) Shaft
Bushing
2 994
(4) Pulleys 2 991
(4) Bracket 3 0045
3 0000
Bracket

Answers to Assignment Sheets

Assignment Sheet 5

A. Clearance $\frac{.7512}{.7505}$ B. Interference $\frac{.7494}{.7483}$

Assignment Sheet 6

Evaluated according to criteria written in the assignment sheet

Assignment Sheet 7

A. 19.8″
B. 63.2″
C. 120°
D. 4.5″
E. 2.8″
F. 2.4″

Dimensioning and Tolerancing
Unit 4

Answers to Written Test

1. a. 4
   b. 7
   c. 9
   d. 12
   e. 6
   f. 3
   g. 1
   h. 5
   i. 8
   j. 11
   k. 10
   l. 2
   m. 22
   n. 18
   o. 28
   p. 20
   q. 26
   r. 14
   s. 25
   t. 24
   u. 16
   v. 23
   w. 21
   x. 27
   y. 17
   z. 13
   aa. 15
   bb. 19

2. a, b, c, f, g, h, i, j, k, o

3. a, b

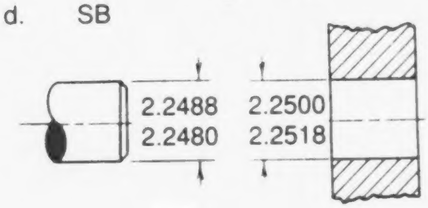
4. a, b, c, d, e

5. a, b, d, e

6. a. R
   b. L
   c. L
   d. R
   e. F
   f. F
   g. R

7. a. HB
   b. S
   c. HI
   d. SB
   e. HB
   f. H
   g. HS

8.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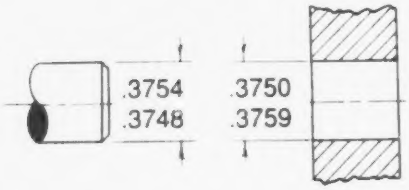
2.2480
2.2500
2.2518

9.


.3754
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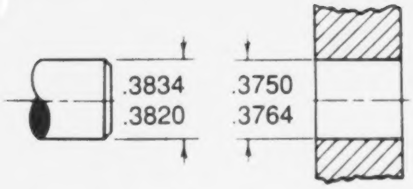
Answers to Written Test

10.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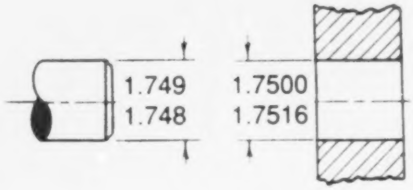
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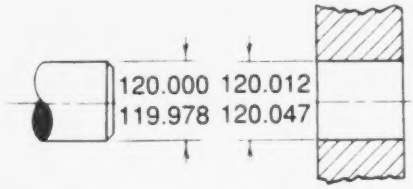
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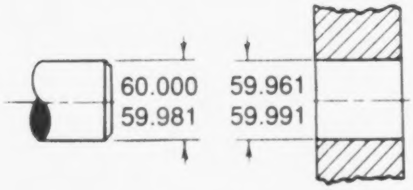
120.012
120.047

13.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59.961
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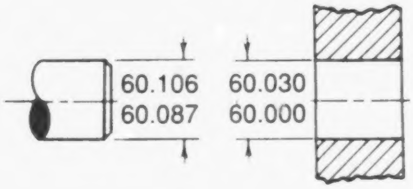
14.


60.106
60.087
60.030
60.000

Answers to Written Test

15. a. .0025 - .010
    b. .0004 - .0025
    c. .006 - .015
    d. .00015 - .0003
    e. The smallest
    f. The largest

16. a, c

17. a, b

18. a, b

19. a. 3
    b. 2
    c. 4
    d. 1
    e. 5

20.

Characteristic Symbols	
Straightness	⏤
Flatness	⏥
Roundness; Circularity	○
Cylindricity	⌭
Profile of a line	⌒
Profile of a surface	⌓
Angularity	∠
Perpendicularity	⊥
Parallelism	//
Position	⌖
Concentricity	◎
Symmetry	⌯
Circular	↗
Total	↗

21. a. 6 d. 5 g. 7
    b. 3 e. 1
    c. 2 f. 4

22. a. 3 d. 1
    b. 6 e. 4
    c. 2 f. 5

Answers to Written Test

23. a. Cylindricity
    b. May have no
    c. Between points
    d. Symmetry

24. a, b, d

25. a

26. b

27. a, b, d, e

28. a, c

29. a. 5 e. 1
    b. 3 f. 4
    c. 6 g. 2
    d. 7

30. a. Sawing, boring, turning, and grinding
    b. A less frequent application
    c. Flame cutting, snagging, sawing, sand casting, and hot rolling (any three of these)
    d. Superfinishing

31. c

32. b, c, d, e, f, g

Dimensioning and Tolerancing
Unit 4

Written Test

Name ______________________________ Date ________________ Score ___________

1. Match the terms on the right with their correct definitions. Terms and definitions continued on the next two pages.

_____a. The minimum international difference in the dimensions of mating parts to provide for different classes of fits; the minimum clearance or maximum interference when parts are at maximum material condition (MMC)

_____b. Measurements of the human body and its parts

_____c. The basic size of the hole is the design size (basic size) and the allowance is applied to the shaft

_____d. The basic size of the shaft is the design size and the allowance is applied to the hole

_____e. The size of a part determined by engineering and design requirements from which the limits of size are determined; the line of zero deviation

_____f. Limits of size are determined so that a loose fit or positive allowance occurs between mating parts

_____g. Points, lines, or other geometric shapes assumed to exact from which the location or geometric form of features of a part may be established

_____h. Maximum allowable variation of a perfect geometric shape

1. Datums
2. Interference fit
3. Clearance fit
4. Allowance
5. Form tolerances
6. Basic size
7. Anthropometric data
8. Fundamental deviation
9. Basic hole system
10. Interchangeability
11. Geometric shapes
12. Basic shaft system
13. Transition fit
14. Lower deviation
15. Upper deviation
16. Roughness
17. Tolerance zone

Written Test

______i. The deviation nearer the basic size for holes and near the basic size for the shaft

______j. Shapes such as prisms, cylinders, pyramids, cones, and spheres

______k. The condition that referes to a part made to limit dimensions so that it will fit any part similarly manufactured; the ability of mating parts to fit properly together

______l. Limits of size are determined so that a negative allowance or tight fit occurs between mating parts

______m. Group of tolerances numbered 01-16

______n. Direction of the major surface pattern determined by manufacturing method used

______o. Use when the least material is present in a feature

______p. The extreme permissible dimensions of a part resulting from the application of a tolerance; the maximum and minimum size indicated by a tolerance

______q. Any type of dimension that locates a feature on an object

______r. Difference between the minimum limit and the basic size

______s. Used when maximum material is present in a feature

______t. Exact theoretical position of a feature established by basic dimensions

______u. Fine irregularities in a surface texture

18. Lay
19. Waviness
20. Limits
21. Surface quality
22. International tolerance grade
23. Size dimension
24. Positional tolerance
25. Maximum material condition
26. Location dimension
27. Tolerance
28. Least material condition

Written Test

_______v. Any type of dimension that tells how large or small an object is

_______w. Roughness, waviness, and lay of a surface which may include certain flaws

_______x. The total amount of variation permitted in limit dimensioning of a part; the difference between the limit dimensions

_______y. The association of a fundamental deviation (letter) with an international tolerance grade (IT) number)

_______z. Limits of size are determined so that the allowance may be either a clearance fit or an interference fit

_______aa. Difference between the maximum limit and the basic size

_______bb. Widely spaced element of a surface texture

2. Select size dimensions for the following geometric shapes. Place an "X" beside each dimension that is a size dimension.

_______a. Dimension "A"

_______b. Dimension "B"

_______c. Dimension "C"

_______d. Dimension "D"

_______e. Dimension "E"

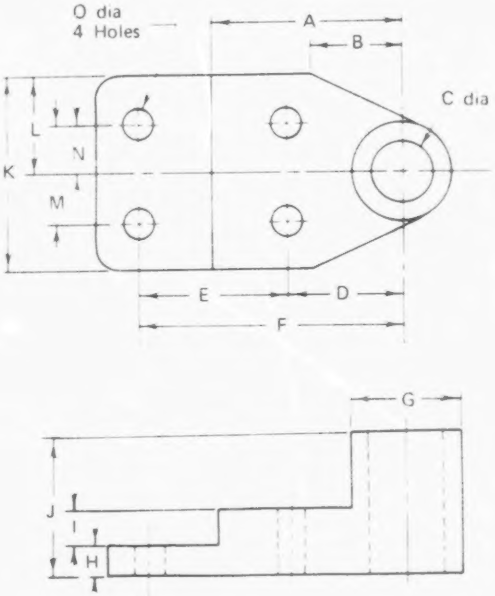
_______f. Dimension "F"

_______g. Dimension "G"

_______h. Dimension "H"

_______i. Dimension "I"

_______j. Dimension "J"



Written Test

______k. Dimension "K"

______l. Dimension "L"

______m. Dimension "M"

______n. Dimension "N"

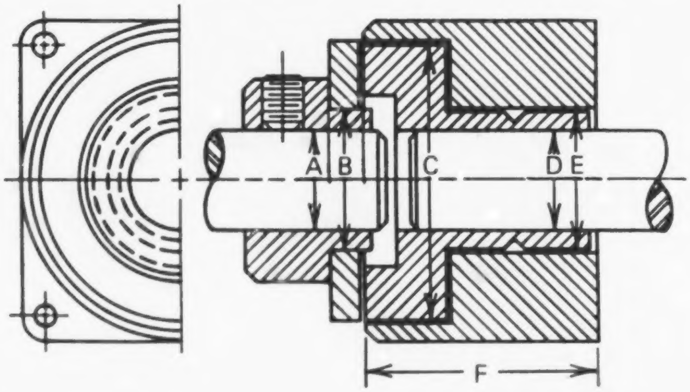
______o. Dimension "O"

3. Select true statements about location dimensions for geometric shapes. Place an "X" beside each true statement.

______a. Rectangular shapes reference their faces.

______b. Cylinders or holes reference to their center lines.

4. Select mating dimensions in the following assembly drawing. Place an "X" beside each dimension that is a mating dimension.



______a. Dimension "A"

______b. Dimension "B"

______c. Dimension "C"

______d. Dimension "D"

______e. Dimension "E"

______f. Dimension "F"

Written Test

5. Select true statements about basic guidelines for numerical control dimensioning. Place an "X" beside each true statement.

_______a. Datum or reference planes must be selected that are mutually perpendicular in the X, Y, and Z axes.

_______b. Dimensions originate from the three planes.

_______c. Dimensions must be in decimals or fractions.

_______d. Angles should be in degrees and decimal parts of degrees.

_______e. Standard tools such as reamers, drills, and tapers should be specified wherever possible.

6. Select fits for inch units and their applications. Place an "R" beside running and sliding fits, place an "L" beside location fits, and place an "F" beside force fits.

_______a. RC 1

_______b. LC 1-LC 11

_______c. LN1-LN2

_______d. RC 7

_______e. FN 3

_______f. FN4-FN5

_______g. RC5-RC6

7. Select fits for metric units and their applications. Place "HB" beside a hole basis clearance fit, "SB" beside a shaft basis clearance fit, "H" beside a hole transition fit, "S" beside a shaft transition fit, "HI" beside a hole interference fit, and "HS" beside a shaft interference fit.

_______a. H 8/f 7

_______b. K 7/h 6

_______c. H 7/s 6

_______d. G 7/h 6

_______e. H 7/g 6

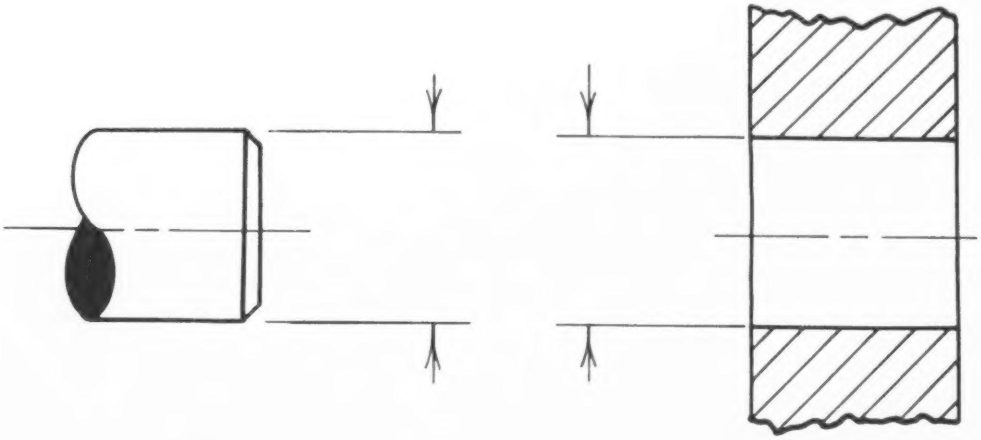
_______f. H 7/k 6

_______g. S 7/h 6

Written Test

8. Calculate the limits for clearance fit in inch units using the basic hole system. Assume a basic hole size of 2.25" and an RC 4 fit. Place your answers appropriately on the following drawing.

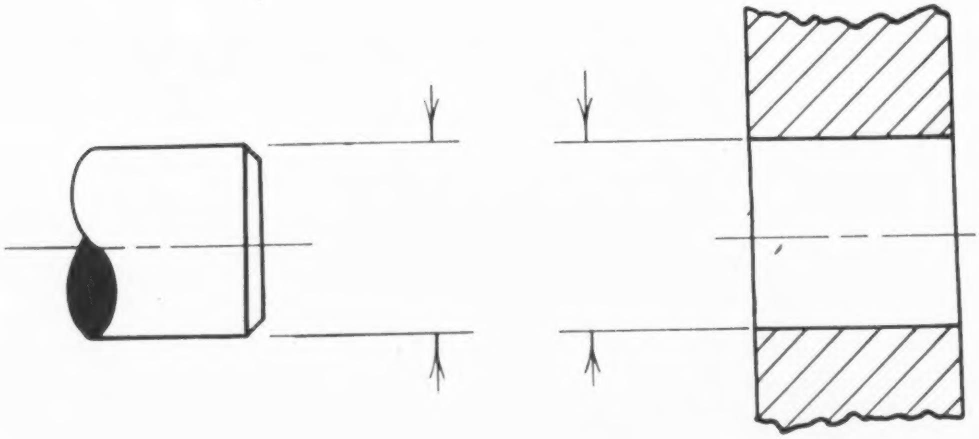
NOMINAL SIZE RANGE INCHES	CLASS: RC3			CLASS: RC4		
	LIMITS OF CLEARANCE	STANDARD LIMITS		LIMITS OF CLEARANCE	STANDARD LIMITS	
		HOLE	SHAFT		HOLE	SHAFT
1.19 - 1.97	-1.0 -2.6	+1.0 -0	-1.0 -1.6	1.0 3.6	+1.6 -0	-1.0 -2.0
1.97 - 3.15	1.2 3.1	+1.2 -0	-1.2 -1.9	1.2 4.2	+1.8 -0	-1.2 -2.4



Written Test

9 Calculate the limits for locational fit in inch units use the basic hole system. Assume a basic hole size of .375" and a LT2 fit. Place your answers appropriately on the following drawing.

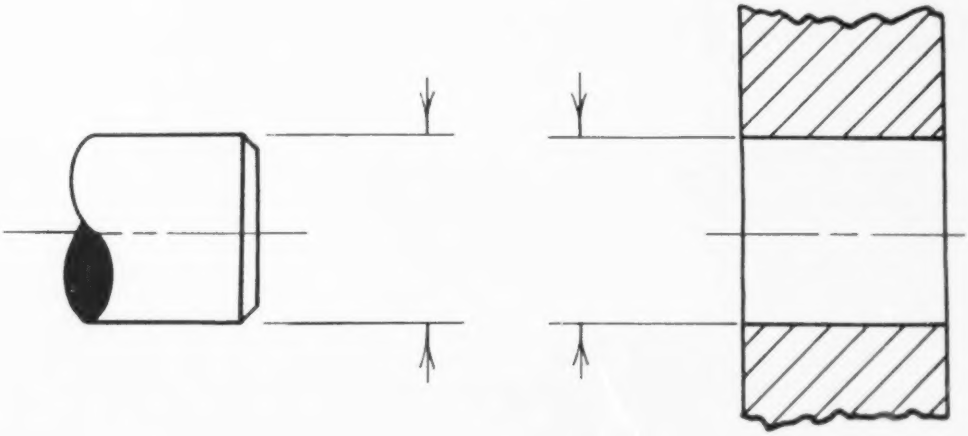
NOMINAL SIZE RANGE INCHES	CLASS: LT1			CLASS: LT2		
	FIT	STANDARD LIMITS		FIT	STANDARD LIMITS	
		HOLE	SHAFT		HOLE	SHAFT
0.04 - 0.12	-0.15 +0.5	+0.4 -0	+0.15 -0.1	-0.3 +0.7	+0.6 -0	+0.3 -0.1
0.12 - 0.24	-0.2 +0.6	+0.5 -0	+0.2 -0.1	-0.4 +0.8	+0.7 -0	+0.4 -0.1
0.24 - 0.40	-0.3 +0.7	+0.6 -0	+0.3 -0.1	-0.4 +1.1	+0.9 -0	+0.4 -0.2
0.40 - 0.71	-0.3 +0.8	+0.7 -0	+0.3 -0.1	-0.5 +1.2	+1.0 -0	+0.5 -0.2



Written Test

10. Calculate the limits for force fit in inch units using the basic hole system. Assume a basic size of 3.75" and a FN 5 class of fit. Place your answers appropriately on the illustration that follows.

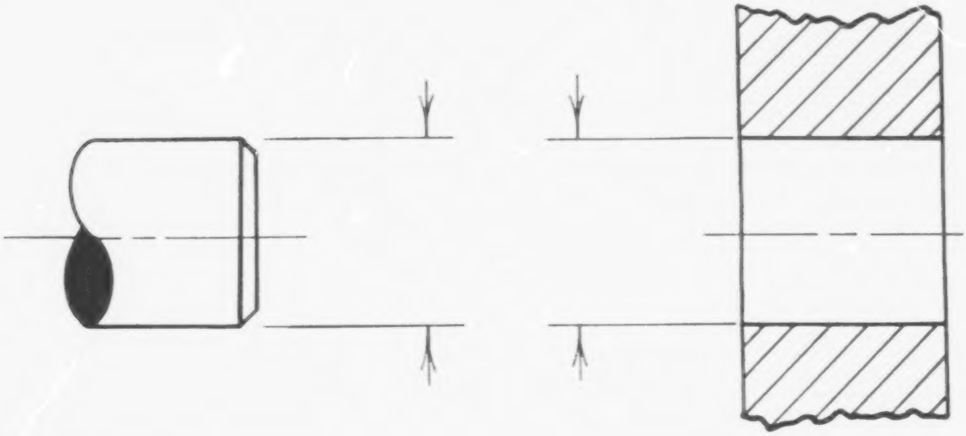
NOMINAL SIZE RANGE INCHES	CLASS: FN4			CLASS: FN5		
	LIMITS OF INTERFERENCE	STANDARD LIMITS		LIMITS OF INTERFERENCE	STANDARD LIMITS	
		HOLE	SHAFT		HOLE	SHAFT
2.56 - 3.15	2.8 4.7	+1.2 -0	+4.7 +4.0	4.8 7.2	+1.2 -0	+7.2 +6.0
3.15 - 3.94	3.6 5.9	+1.4 -0	+5.9 +5.0	5.6 8.4	+1.4 -0	+8.4 +7.0
3.94 - 4.73	4.6 6.9	+1.4 -0	+6.9 +6.0	6.6 9.4	+1.4 -0	+9.4 +8.0



Written Test

11. Calculate the limits for clearance fit in inch units using the basic hole size system. Assume a shaft size of 1.75 and an RC 3 fit. Place your answers appropriately on the illustration that follows.

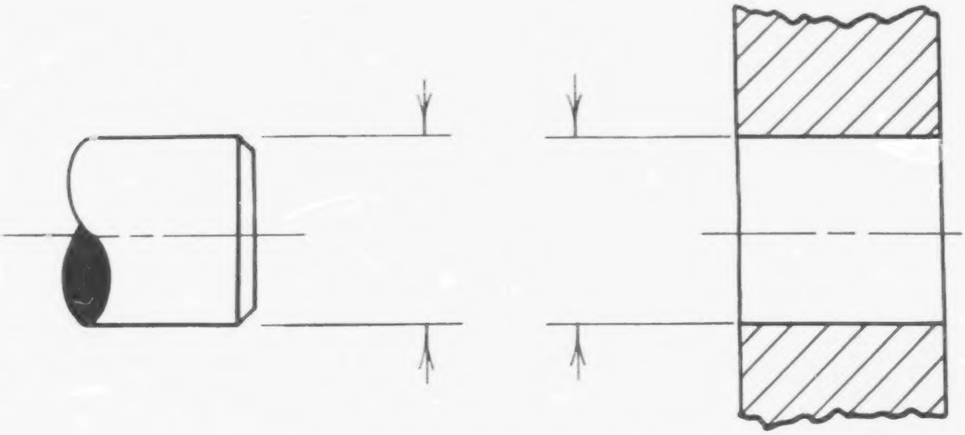
NOMINAL SIZE RANGE INCHES	CLASS: RC3			CLASS: RC4		
	LIMITS OF CLEARANCE	STANDARD LIMITS		LIMITS OF CLEARANCE	STANDARD LIMITS	
		HOLE	SHAFT		HOLE	SHAFT
1.19 - 1.97	1.0 2.6	+1.0 -0	-1.0 -1.6	1.0 3.6	+1.6 -0	-1.0 -2.0
1.97 - 3.15	1.2 3.1	+1.2 -0	-1.2 -1.9	1.2 4.2	+1.8 -0	-1.2 -2.4



Written Test

12. Calculate the limits for clearance fit in metric units using the basic shaft system. Assume a basic size of 120mm and a sliding fit G7/h6. Place your answers appropriately on the illustration that follows.

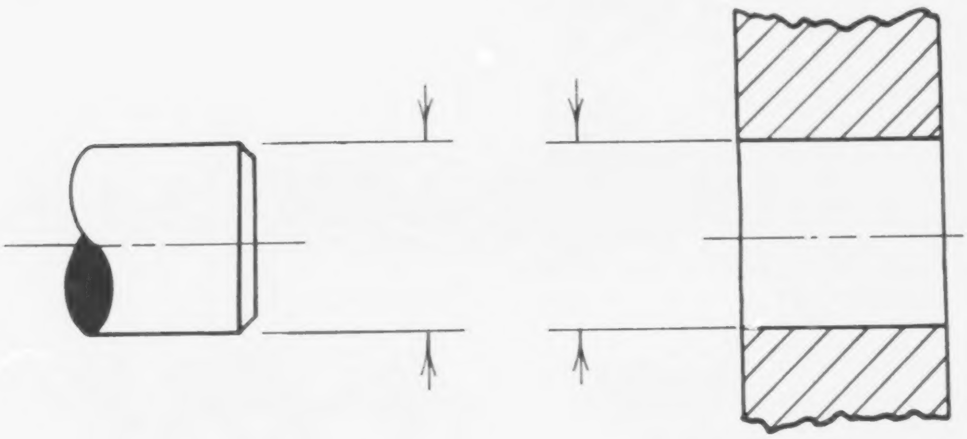
BASIC SIZE METRIC		CLOSE RUNNING			SLIDING		
		FIT	STANDARD LIMITS		FIT	STANDARD LIMITS	
			HOLE F8	SHAFT h7		HOLE G7	SHAFT h6
120	MAX	0.125	120.090	120.000	0.069	120.047	120.000
	MIN	0.036	120.036	119.965	0.012	120.012	119.978



Written Test

13. Calculate the limits for a transition fit in metric units using the basic shaft system. Assume a basic size of 60 locational transition fit F8/h7. Place your answers appropriately on the following drawing.

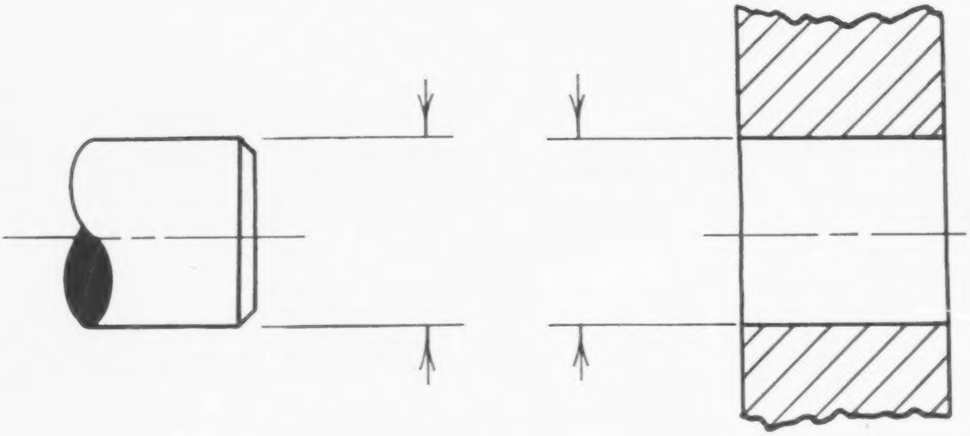
BASIC SIZE METRIC		LOCATIONAL TRANSITION		
		FIT	STANDARD LIMITS	
			HOLE F8	SHAFT h7
50	MAX	0.008	49.992	50.000
	MIN	-0.033	49.967	49.984
60	MAX	0.010	59.991	60.000
	MIN	-0.039	59.961	59.981



Written Test

14. Calculate the limits for an interference fit in metric units using the basic hole system. Assume a basic hole size of 60mm and a H7/u6 fit. Place your answers appropriately on the following drawing.

BASIC SIZE METRIC		FORCE		
		FIT	STANDARD LIMITS	
			HOLE H7	SHAFT u6
60	**MAX**	-0.057	60.030	60.106
	MIN	-0.106	60.000	60.087
80	**MAX**	-0.072	80.030	80.121
	MIN	-0.121	80.000	80.102



Mechanical Drafting With CAD, Unit 4
Teacher Page 24

Written Test

15. Determine tolerance ranges and their relationship to costs and shop processes. Refer to the chart below to answer the questions that follow.

    a. What would be the full range of tolerances for the milling of a 1.5" to 2.799" part?

       Answer ____________________

    b. What would be the full range of tolerances for the reaming of a .6" to .999" part?

       Answer ____________________

    c. What would be the full range of tolerances for the drilling of a 4.5" to 7.799" part?

       Answer ____________________

    d. What would be the full range of tolerances for the honing of a .000" to .599" part?

       Answer ____________________

    e. Since lapping and honing are the most expensive shop processes, do they produce the largest or smallest tolerances?

       Answer ____________________

    f. Since milling and drilling produce the least expensive shop processes, do they produce the largest or smallest tolerances?

       Answer ____________________

16. Select true statements about guidelines for determining clearance fit on standard dowels. Place an "X" beside each true statement.

    _______a. The tightest fit = MMC hole - MMC shaft.

    _______b. The loosest fit = LMC hole + LMC shaft.

    _______c. Limits of clearance: smallest number is the tightest fit; largest number is the loosest fit.

Written Test

17. Select true statements about guidelines for determining interference fit on standard dowels. Place an "X" beside each true statement.

_______a. The tightest fit = MMC hole - MMC shaft.

_______b. The loosest fit = LMC hole - LMC shaft.

_______c. Limits of interference: largest number is the loosest fit and is negative; smallest number is the tightest fit and is positive.

18. Select true statements about guidelines for determining limit dimensions for the interchangeability of parts. Place an "X" beside each true statement.

_______a. Parts should be toleranced to fit end-for-end to make assembly easier if function is not affected.

_______b. Select the center dimension to be basic size.

_______c. Maximum accumulation should be added to center.

_______d. When each part is toleranced, it is not necessary to check the accumulation of tolerance.

19. Arrange in order the steps for determining limit dimensions for intermediate parts to retain overall limits. Place a "1" beside the first step, a "2" beside the second step, and continue in order until all steps are properly numbered.

_______a. Divide total tolerance accumulation by number of toleranced parts to get tolerance per part

_______b. Subtract upper and lower limits of overall dimension to get total tolerance accumulation

_______c. Add tolerance per part to each basic size to get upper limit of each part

_______d. Find limit dimensions

_______e. Check by adding upper limits together to get upper limit of overall dimension

Written Test

20. Complete the following chart of ANSI and ISO symbols for tolerance of position and form. Sketch the missing symbols and insert missing terms.

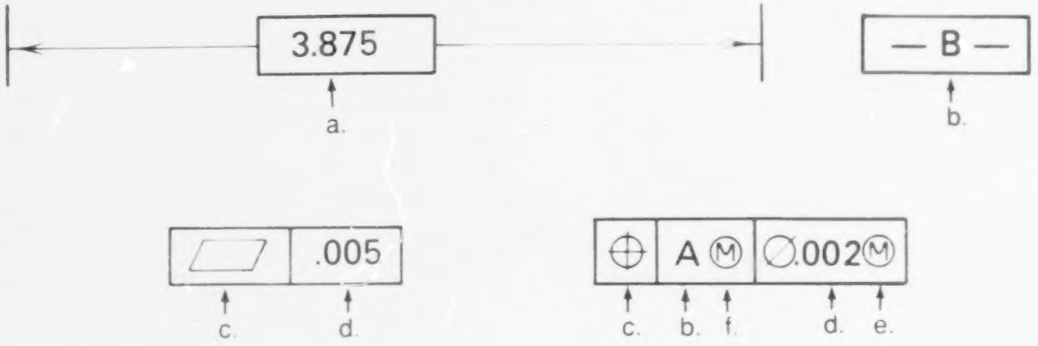
Characteristic Symbols	
Straightness	—
Flatness	
	○
Cylindricity	⌭
Profile of a line	⌒
Profile of a surface	⌓
Angularity	∠
Perpendicularity	
	//
Position	⌖
Concentricity	◎
Symmetry	
Circular	↗
Total	↗

21. Match ANSI modifying symbols and terms for tolerances of position and form. Place the number of the term in the blank beside the correct symbol.

______a. Ⓢ	1. Diameter
______b. Ⓜ	2. Basic dimension
______c. ▭	3. At maximum material condition
______d. ( )	4. Projected tolerance zone
______e. ⌀	5. Reference dimension
______f. Ⓟ	6. Regardless of feature size
______g. Ⓛ	7. At least material condition

Written Test

22. Identify position and form symbols in a drawing. Place the number of the symbols in the blank beside its definition.



______a. Geometric characteristic symbol

______b. Modifier of datum

______c. Datum reference

______d. Basic dimension symbol

______e. Tolerance

______f. Modifier of tolerance

23. Complete statements about descriptions of position and form. Circle the material that best completes each of the following statements.

a. Basic descriptions of position and form include straightness, flattness, roundness, and (**cylindricity**) (**angularity**).

b. A description (**may have**) (**may have no**) specified tolerance of form.

c. Profile descriptions concern the profile of a surface, or the profile of a surface (**on an incline**) (**between points**).

d. Descriptions for orientation concern angularity, perpendicularity, parallelism, and (**flatness**) (**symmetry**).

e. Descriptions for location involve position and (**symmetry**) (**concentricity**).

Written Test

24. Select true statements about positional tolerancing. Place an "X" beside each true statement.

______ a. Positional tolerancing depends on the type of zone: in conventional limit location dimensions, the tolerance zone is square, but positional tolerancing allows for a circular zone.

______ b. In cylindrical tolerance zones, positional tolerancing allows more tolerance than conventional limit dimensions.

______ c. Tolerance accumulation is allowed in positional tolerancing.

______ d. Positional tolerancing does permit variations, such as the extreme angular variation for drilling a hole.

25. Differentiate between features of MMC and RFS. Place an "X" beside the definition of MMC.

______ a. Is less restrictive.

______ b. Is more restrictive.

26. Select true statements about angular tolerances. Place an "X" beside each true statement.

______ a. Bilateral angular tolerances cause a smaller tolerance zone when moving from the vertex.

______ b. Because of the use of angular feature controls, basic angular tolerances cause a parallel tolerance zone.

27. Differentiate between correct and incorrect placement of surface quality symbols. Place "C" in the blanks beside symbols that have been correctly placed.

______ a.

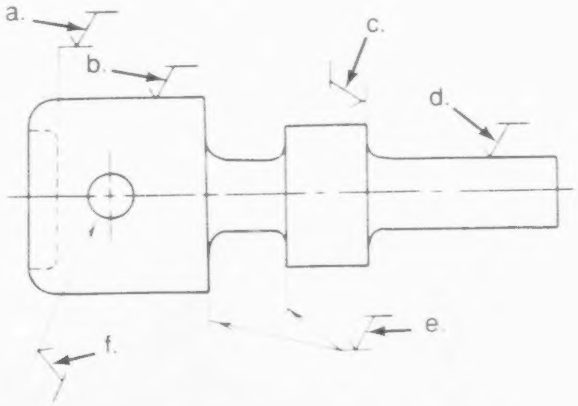
______ b.

______ c.

______ d.

______ e.

______ f.



Written Test

28. Select true statements about surface quality notes. Place an "X" beside each true statement.

______a. Surface quality notes are dedicated to helping achieve an important manufacturing objective: to provide the roughest surface that will satisfy function and form.

______b. Values in notes are expressed in micrometers or microinches, and the higher the micrometer or microinch, the finer the surface.

______c. The quality symbol is always made in the standard upright position.

29. Match lay symbols with their meanings. Place the number beside the meaning in the blank beside the symbol it defines.

______a. =

______b. ⊥

______c. X

______d. M

______e. C

______f. R

______g. p^3

1. Circular
2. Particulate, nondirectional, or protuberant
3. Perpendicular to surface
4. Radial
5. Parallel to surface
6. Angular to surface
7. Multidirectional

Written Test

30. Evaluate production processes and the degrees of surface roughness they produce. Reference the following chart and answer the questions.

    a. What four processes span the widest ranges of surface roughness?

    Answer ____________________

    b. Would milling to a surface roughness of 16 microinches be considered an average application or a less frequent application?

    Answer ____________________

    c. Name at least three processes that would produce the roughest surfaces?

    Answers ____________________ ____________________ ____________________

    d. If you had to select an average application that would produce the least rough surface, would you select polishing or superfinishing?

    Answer ____________________

Written Test

31. Select recommended values for surface quality roughness. Place an "X" in the blank or blanks beside recommended values.

Recommended Roughness
Average Rating Values
Micrometers (Microinches)

μm	μin.	μm	μin.
0.025	(1)	1.25	(50)
0.050	**(2)**	**1.6**	**(63)**
0.075	(3)	2.0	(80)
0.100	**(4)**	2.5	(100)
0.125	(5)	**3.2**	**(125)**
0.15	(6)	4.0	(160)
0.20	**(8)**	5.0	(200)
0.25	(10)	**6.3**	**(250)**
0.32	(13)	8.0	(320)
0.40	**(16)**	10.0	(400)
0.50	(20)	**12.5**	**(500)**
0.63	(25)	15.0	(600)
0.80	**(32)**	20.0	(800)
1.00	(40)	25.0	(1000)

Recommended Waviness
Height Values,
Millimeters (Inches)

mm	in.	mm	in.
0.0005	**(.00002)**	**0.025**	**(.0010)**
0.008	(.00003)	**0.05**	**(.002)**
0.0012	**(.00005)**	0.08	(.003)
0.0020	(.0008)	**0.12**	**(.005)**
0.0025	**(.00010)**	0.20	(.008)
0.005	**(.0002)**	**0.25**	**(.010)**
0.008	(.0003)	0.38	(.015)
0.012	**(.0005)**	**0.50**	**(.020)**
0.020	(.0008)	0.80	(.030)

Recommended
Standard Roughness
Width Cutoff Values
Millimeters (Inches)

mm	in.	mm	in.
0.08	(0.03)	2.50	(.100)
0.25	(.013)	8.0	(.300)
0.80	**(.030)**	25.0	(1.000)

______a. .075 μm Roughness

______b. .20 mm Waviness height

______c. .80 mm Roughness width cutoff

***Permission to duplicate this test is granted.**

Dimensioning and Tolerancing
Unit 4

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Dimension an Object Completely Rating ______

Comments: ____

____

Assignment Sheet 2—Calculate and Dimension Clearance Fit Tolerances Using Standard Fit Tables Rating ______

Comments: ____

____

Assignment Sheet 3—Calculate and Dimension Interference Fit Tolerances using Standard Fit Tables Rating ______

Comments: ____

____

Assignment Sheet 4—Calculate and Assign Tolerances to Mating Parts Using Standard Fit Tables Rating ______

Comments: ____

____

Assignment Sheet 5—Calculate and Dimension Hole-Size Limits For Standard Dowels Rating ______

Comments: ____

____

Assignment Sheet 6—Dimension an Object Using Position and Form Tolerances Rating ______

Comments: ____

____

Unit Evaluation Form

Assignment Sheet 7—Determine Ranges of Motion of Limbs and Spaces Required For a Person Rating ______

Comments: ____

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

Teacher Signature ______________________ Date ____________

Student Signature ______________________ Date ____________

*Permission to duplicate this form is granted.

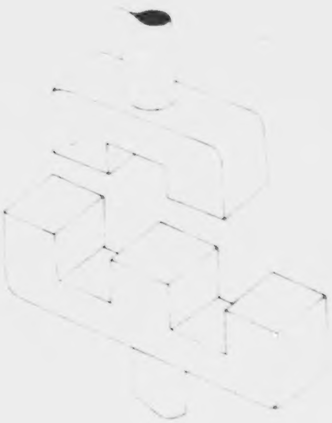
Dimensioning and Tolerancing
Unit 4

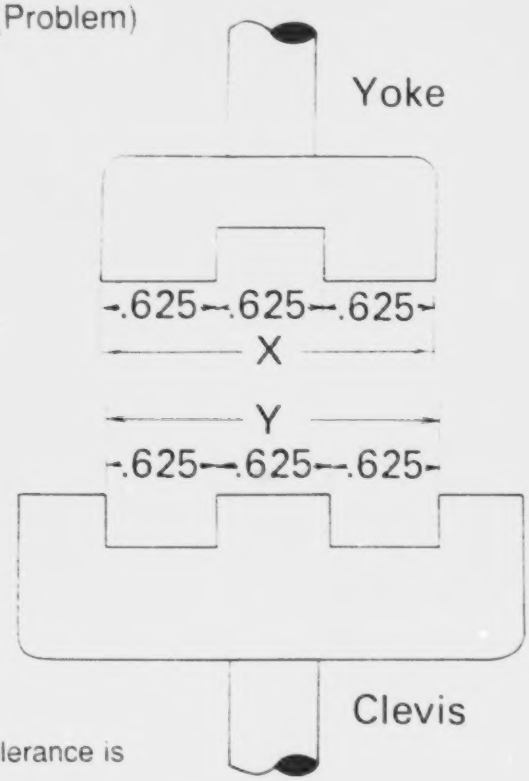
Teacher Supplement 1—Calculating Interchangeability of Mating Parts

Note: The materials in this supplement may be copied for use as additional test items or as supplemental items for students to earn extra credit.

Read the problem carefully, then apply the step-by step calculations on the following page.

(Problem)



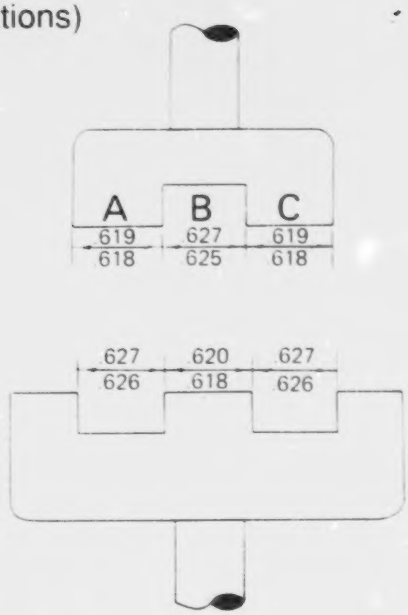


Data:

A. Basic sizes are as indicated.
B. Maximum accumulation of tolerance is .004 which may be X or Y.
C. Required clearance allowance between each set of mating components is .005
D. Loosest fit not to exceed .015.
E. Dimension each component on the yoke and also on the clevis, in limit form so that the fit requirements are maintained.
F. Dimension so that yoke can be turned end-for-end and the parts will assemble with required clearance values.

Teacher Supplement 1

(Calculations)



1. Yoke (B) MMC .625
   Clearance - .005
   Clevis (B) MMC .620

2. (B) .002 Tol dist.
   (A) .001 Tol dist.
   (C) .001 Tol dist.
   .004 Max Accum

3. Yoke (B) MMC .625
   (B) Tol +.002
   Yoke (B) LMC .627

4. Clevis (B) MMC .620
   (B) Tol - .002
   Clevis (B) LMC .618

5. Clevis (A) or (B) LMC
   = .627
   (From Yoke [B] LMC)

6. Clevis (A) or (B) LMC .627
   Tol dist. - .001
   Clevis (A) or (B) MMC .626

7. Yoke (A) or (B) LMC
   = .618

8. Yoke (A) or (B) LMC .618
   Tol dist. +.001
   Yoke (A) or (B) MMC .619

9. Check Maximum and Minimum

Max of Yoke	Min of Yoke	Max of Clevis	Min of Clevis
.619	.618	.627	.626
.627	.625	.620	.618
.619	.618	.627	.626
1.865	1.861	1.874	1.870

1.870 - 1.865 = .005 (Within Overall Clearance)
1.874 - 1.861 = .013 (Within Loosest Fit)

Dimensioning and Tolerancing
Unit 4

Teacher Supplement 2—Calculating Limits For Intermediate Parts

Note: The materials in this supplement may be copied for use as additional test items or as supplemental items for students to earn extra credit.

Read the problem carefully, and see if you put the correct limit figures in place before you have to check the answers on the reverse of this page.

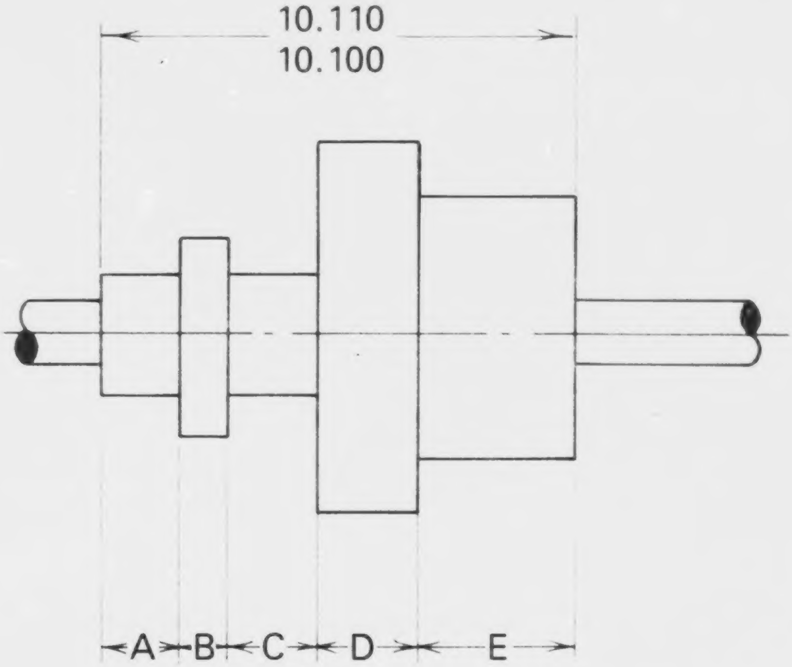
A. Dimension the Intermediate Parts to Retain Overall Limits.

B. Use Largest Possible Tolerance.

C. Give Dimensions in Limit Form.

Basic Size

A	1.500
B	1.350
C	1.500
D	2.000
E	3.750



Limits

A. ____________ B. ____________ C. ____________

D. ____________ E. ____________

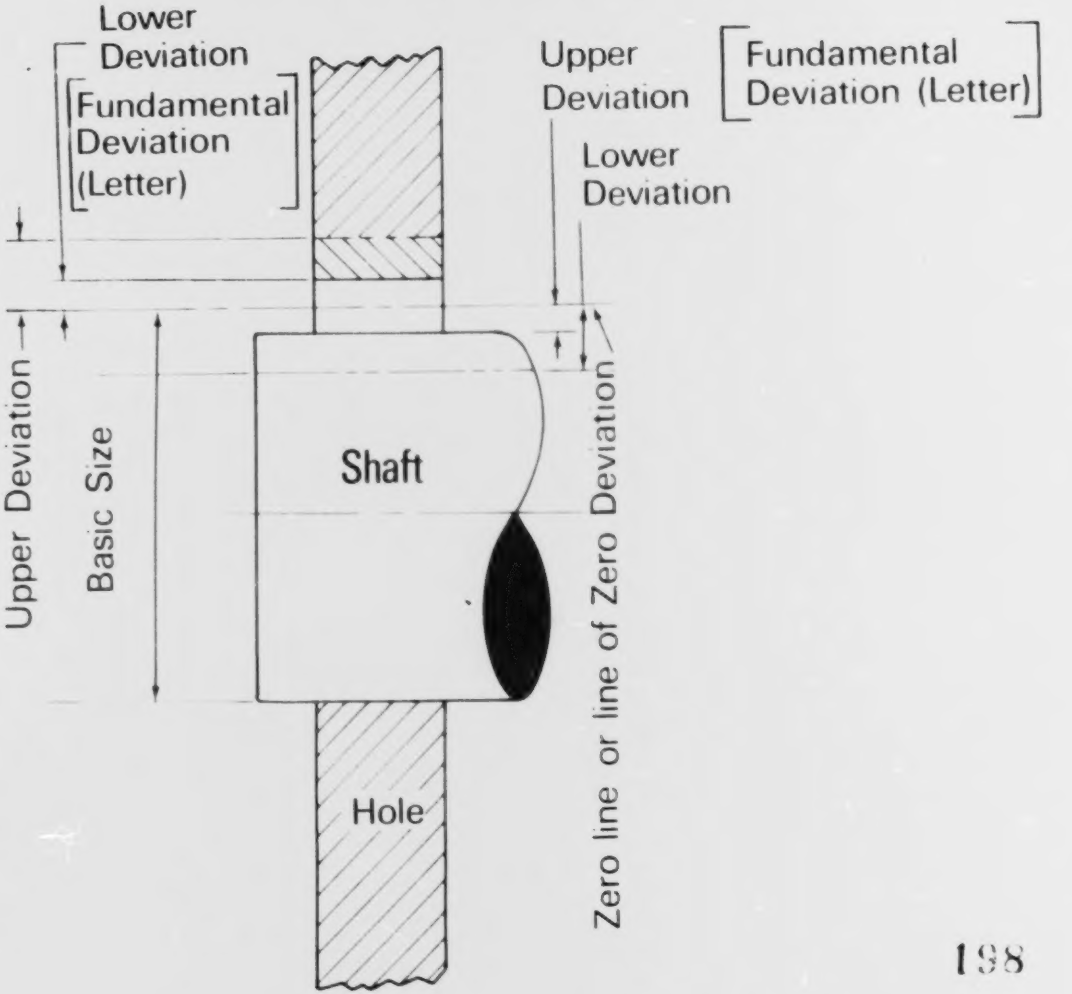
Teacher Supplement 2

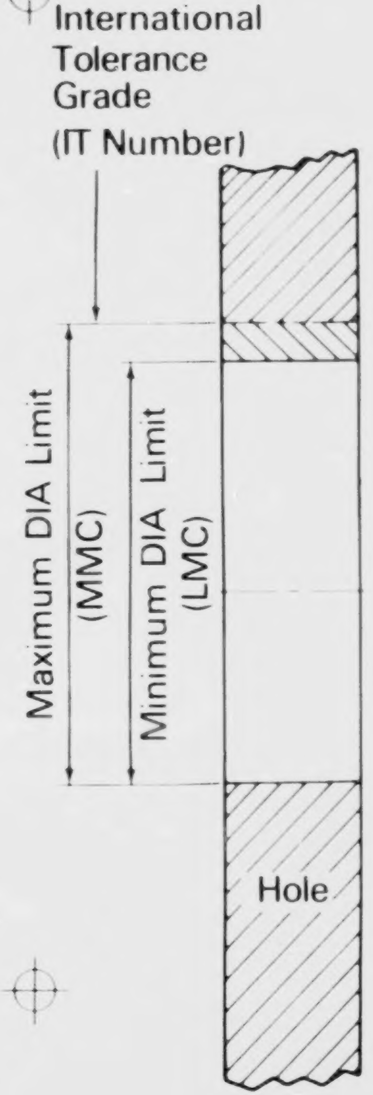
ANSWERS

A. $\begin{matrix}1.502\\ \underline{1.500}\end{matrix}$ B. $\begin{matrix}1.352\\ \underline{1.350}\end{matrix}$ C. $\begin{matrix}1.502\\ \underline{1.500}\end{matrix}$

D. $\begin{matrix}2.002\\ \underline{2.000}\end{matrix}$ E. $\begin{matrix}3.752\\ \underline{3.750}\end{matrix}$

Tolerancing Terms


Lower Deviation
Fundamental Deviation (Letter)
Upper Deviation
Fundamental Deviation (Letter)
Lower Deviation
Upper Deviation
Basic Size
Shaft
Hole
Zero line or line of Zero Deviation


International
Tolerance
Grade
(IT Number)
Maximum DIA Limit
(MMC)
Minimum DIA Limit
(LMC)
Hole

Mechanical Drafting With CAD Unit 4
Teacher Page 41

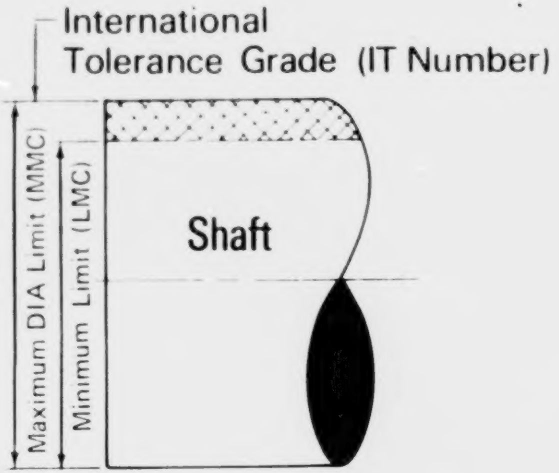
Overlay 1A

199

200

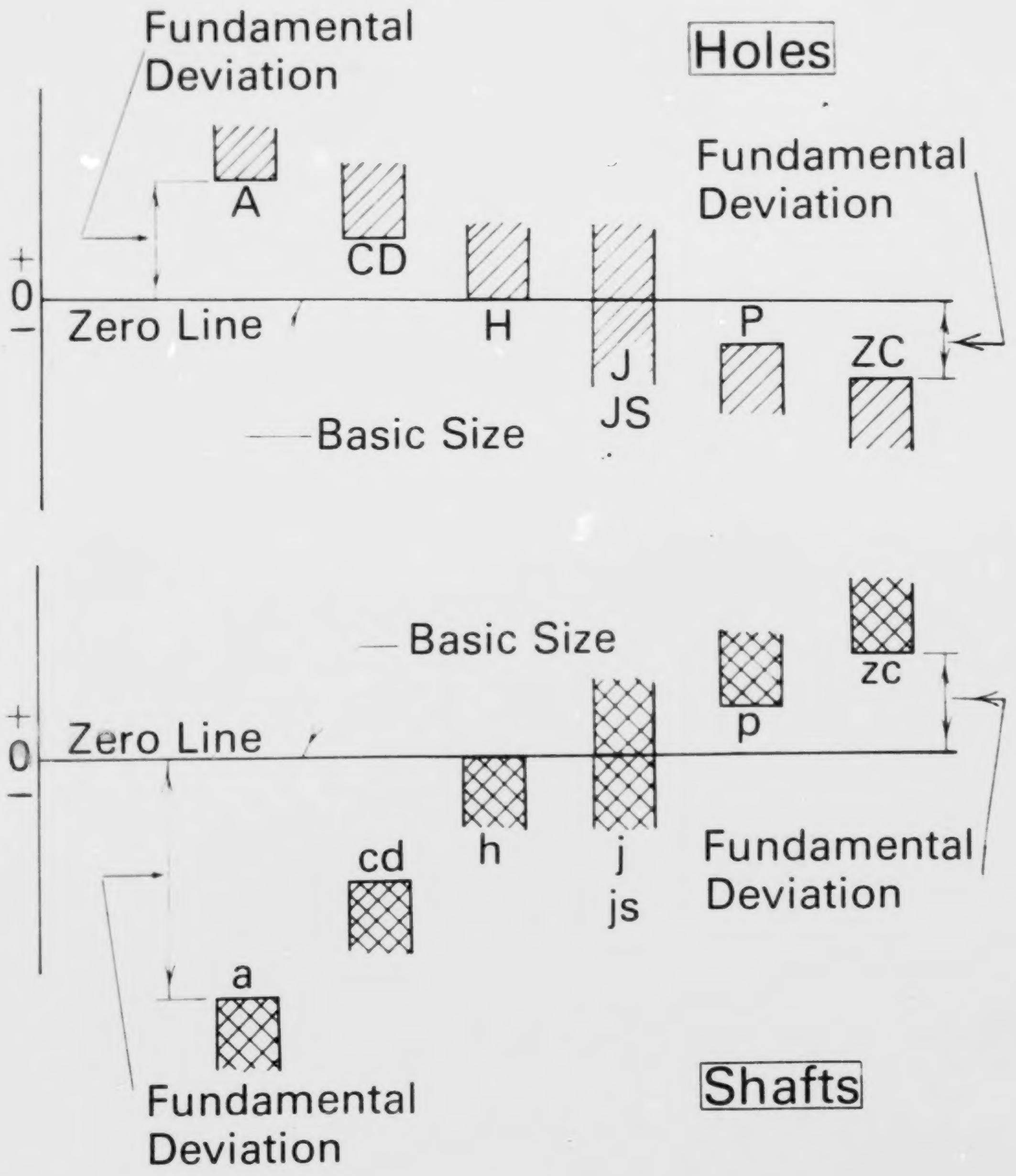
Mechanical Drafting With CAD Unit 4
Teacher Page 43

Overlay 1B

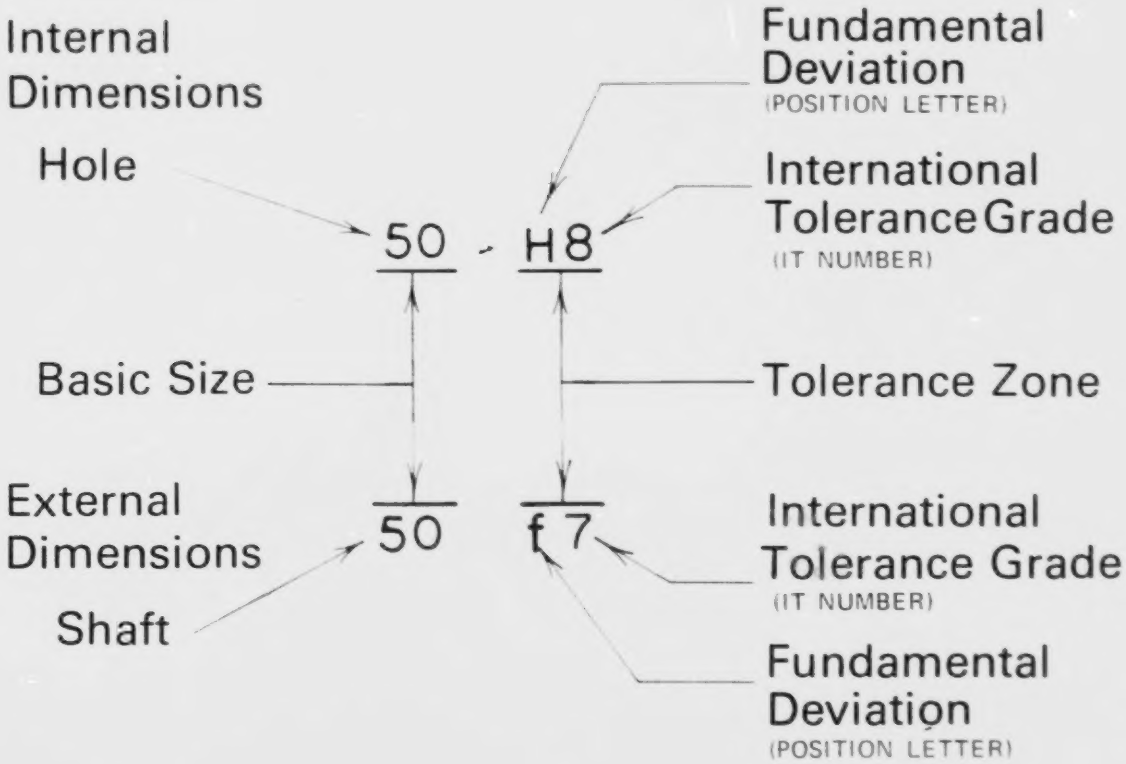

International Tolerance Grade (IT Number)
Maximum DIA Limit (MMC)
Minimum Limit (LMC)
Shaft

Graphical Representation of Tolerance Zones

(Metric)


Fundamental Deviation
Holes
Fundamental Deviation
A
CD
+
0
−
Zero Line
H
J
JS
P
ZC
Basic Size
Basic Size
zc
p
+
0
−
Zero Line
h
j
js
cd
a
Fundamental Deviation
Fundamental Deviation
Shafts

Metric Tolerance Designation



Internal Dimensions

Hole

Fundamental Deviation (POSITION LETTER)

International Tolerance Grade (IT NUMBER)

50 - H8

Basic Size

Tolerance Zone

External Dimensions

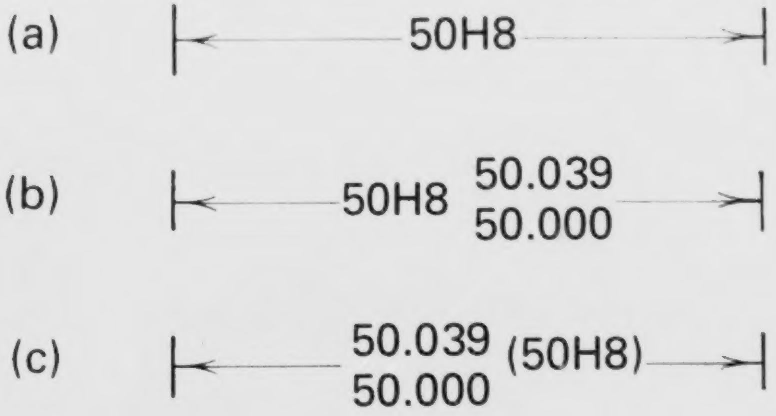
Shaft

50 f 7

International Tolerance Grade (IT NUMBER)

Fundamental Deviation (POSITION LETTER)

Designations of Tolerances on Drawings

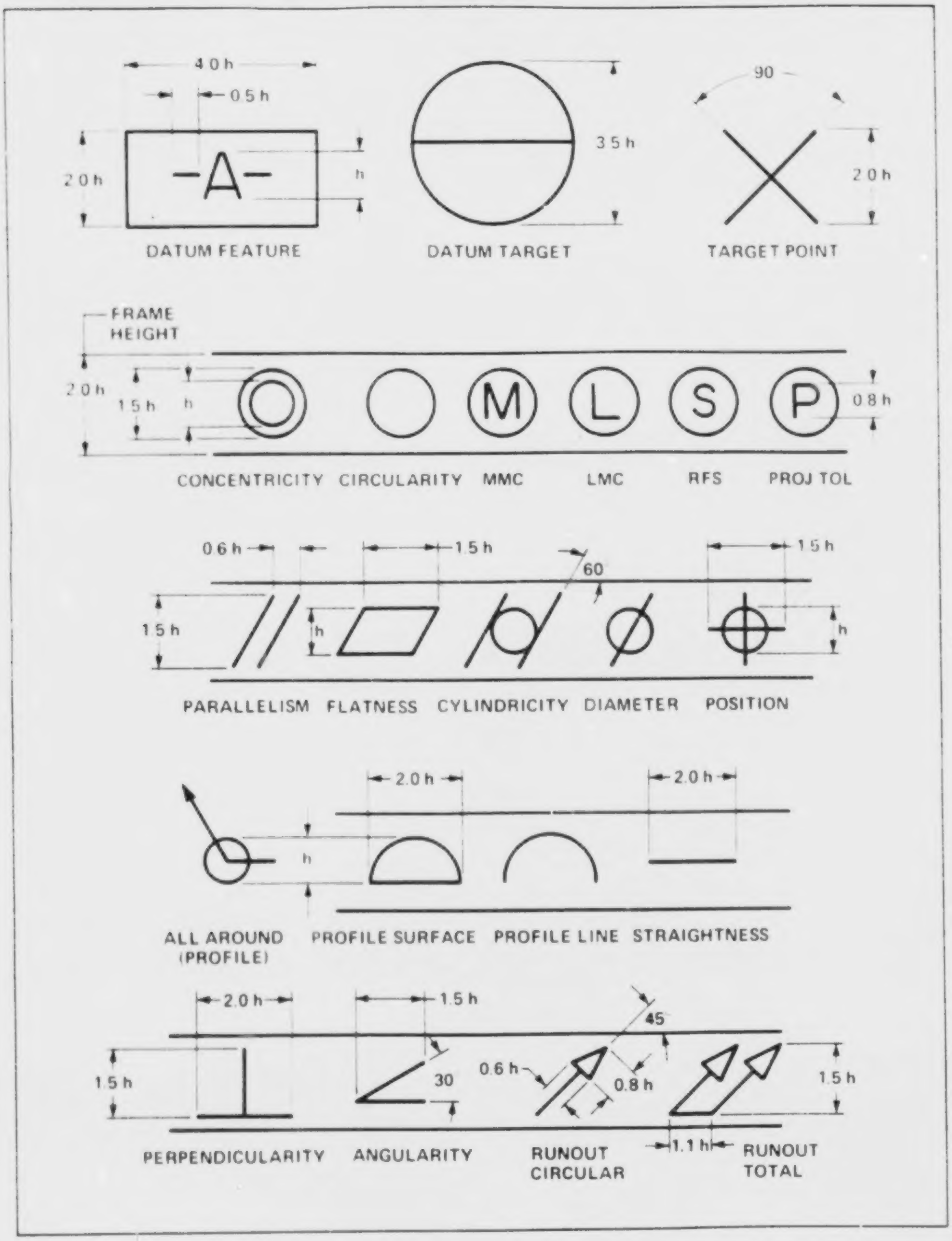


(a) 50H8

(b) 50H8 $\frac{50.039}{50.000}$

(c) $\frac{50.039}{50.000}$ (50H8)

Form and Proportion of Geometric Tolerancing Symbols


4.0 h
0.5 h
2.0 h
-A-
h
DATUM FEATURE
3.5 h
DATUM TARGET
90
2.0 h
TARGET POINT
FRAME HEIGHT
2.0 h
1.5 h
h
0.8 h
M
L
S
P
CONCENTRICITY
CIRCULARITY
MMC
LMC
RFS
PROJ TOL
0.6 h
1.5 h
60
1.5 h
1.5 h
h
h
PARALLELISM
FLATNESS
CYLINDRICITY
DIAMETER
POSITION
2.0 h
2.0 h
h
ALL AROUND (PROFILE)
PROFILE SURFACE
PROFILE LINE
STRAIGHTNESS
2.0 h
1.5 h
45
1.5 h
30
0.6 h
0.8 h
1.5 h
1.1 h
PERPENDICULARITY
ANGULARITY
RUNOUT CIRCULAR
RUNOUT TOTAL

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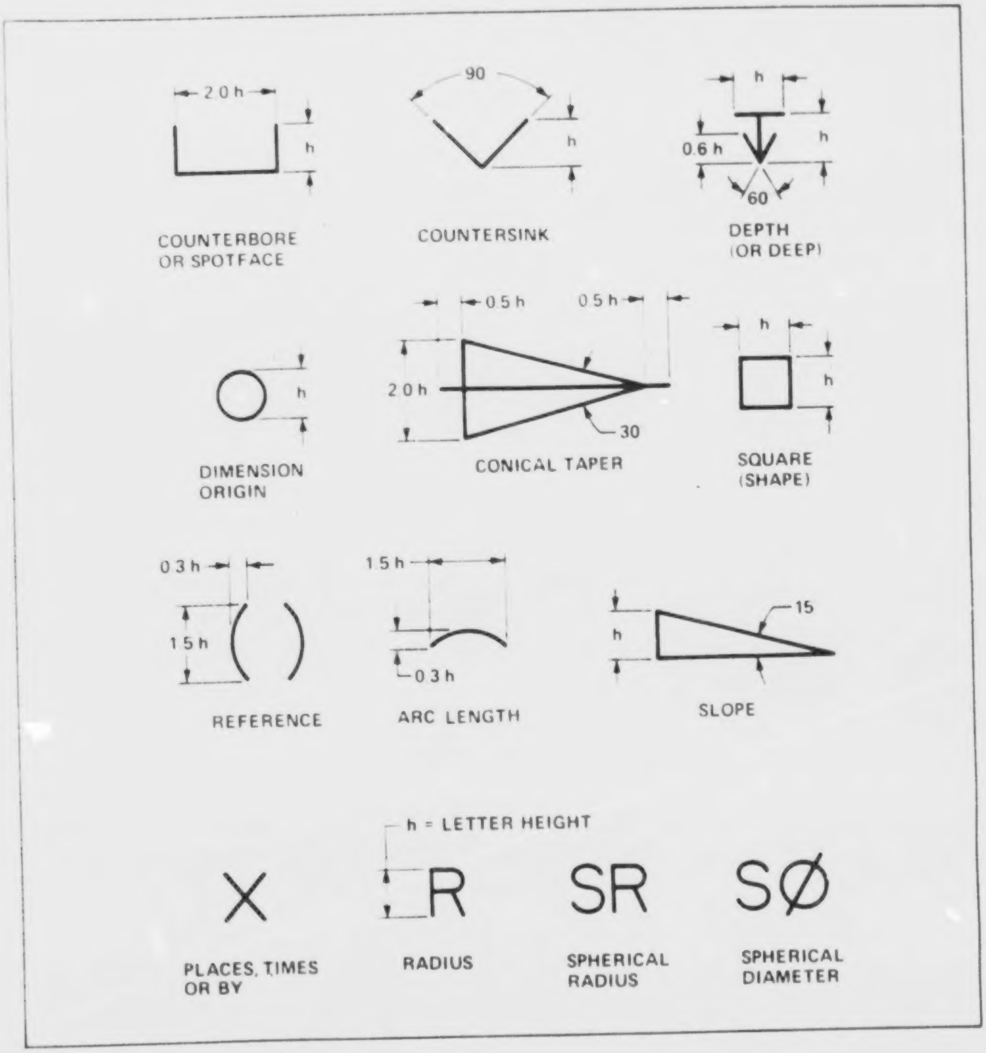
Form and Proportion of Dimensioning Symbols


2.0 h
h
COUNTERBORE OR SPOTFACE
90
h
COUNTERSINK
h
0.6 h
h
60
DEPTH (OR DEEP)
h
DIMENSION ORIGIN
0.5 h
0.5 h
2.0 h
30
CONICAL TAPER
h
h
SQUARE (SHAPE)
0.3 h
1.5 h
REFERENCE
1.5 h
0.3 h
ARC LENGTH
h
15
SLOPE
h = LETTER HEIGHT
X
PLACES, TIMES OR BY
R
RADIUS
SR
SPHERICAL RADIUS
SØ
SPHERICAL DIAMETER

From ANSI 14.5M - 1982
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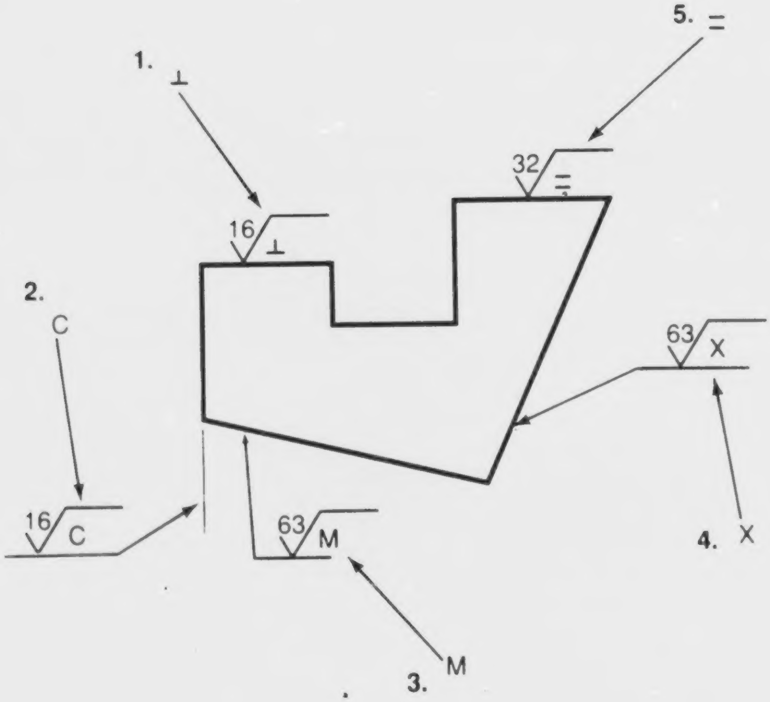
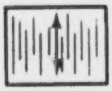
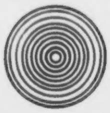
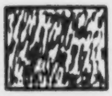
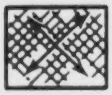
Lay Symbols

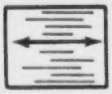


1.  Lay is approximately perpendicular to the line representing the surface to which the symbol is applied.

2.  Lay is approximately circular relative to the center of the surface to which the symbol is applied.

3.  Lay is multidirectional.

4.  Lay is angular in both directions to line representing the surface to which the symbol is applied.

5.  Lay is approximately parallel to the line representing the surface to which the symbol is applied.

Dimensioning and Tolerancing
Unit 4

Information Sheet

1. **Terms and definitions**

   a. **Allowance** — The minimum international difference in the dimensions of mating parts to provide for different classes of fits; the minimum clearance or maximum interference when parts are at maximum material condition (MMC)

   b. **Anthropometric data** — Measurements of the human body and its parts

   c. **Basic hole system** — The basic size of the hole is the design size (basic size) and the allowance is applied to the shaft

   d. **Basic shaft system** — The basic size of the shaft is the design size and the allowance is applied to the hole

      Note: The fundamental deviation for a shaft system is h.

   e. **Basic size** — The size of a part determined by engineering and design requirements from which the limits of size are determined; the line of zero deviation

   f. **Clearance fit** — Limits of size are determined so that a loose fit or positive allowance occurs between mating parts

   g. **Datums** — Points, lines, or other geometric shapes assumed to exact from which the location or geometric form of features of a part may be established

   h. **Form tolerances** — Maximum allowable variation of a perfect geometric shape

   i. **Fundamental deviation** —The deviation nearer the basic size for holes and near the basic size for the shaft

   j. **Geometric shapes** — Shapes such as prisms, cylinders, pyramids, cones, and spheres

   k. **Interchangeability** — The condition that referes to a part made to limit dimensions so that it will fit any part similarly manufactured; the ability of mating parts to fit properly together

   l. **Interference fit** — Limits of size are determined so that a negative allowance or tight fit occurs between mating parts

   m. **International tolerance grade** — Group of tolerances numbered 01-16

Information Sheet

n. **Lay** — Direction of the major surface pattern determined by manufacturing method used

o. **Least material condition (LMC)** — Use when the least material is present in a feature

p. **Limits** — The extreme permissible dimensions of a part resulting from the application of a tolerance; the maximum and minimum size indicated by a tolerance

q. **Location dimension** — Any type of dimension that locates a feature on an object

r. **Lower deviation** — Difference between the minimum limit and the basic size

s. **Maximum material condition (MMC)** — Used when maximum material is present in a feature

t. **Positional tolerance** — Exact theoretical position of a feature established by basic dimensions

u. **Roughness** — Fine irregularities in a surface texture

v. **Size dimension** — Any type of dimension that tells how large or small an object is

w. **Surface quality** — Roughness, waviness, and lay of a surface which may include certain flaws

x. **Tolerance** — The total amount of variation permitted in limit dimensioning of a part; the difference between the limit dimensions

y. **Tolerance zone** — The association of a fundamental deviation (letter) with an international tolerance grade (IT) number)

z. **Transition fit** — Limits of size are determined so that the allowance may be either a clearance fit or an interference fit

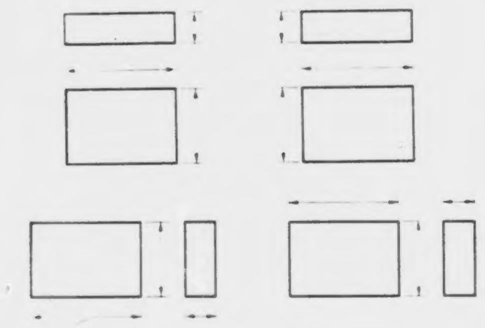
aa. **Upper deviation** — Difference between the maximum limit and the basic size

bb. **Waviness** — Widely spaced element of a surface texture

Information Sheet

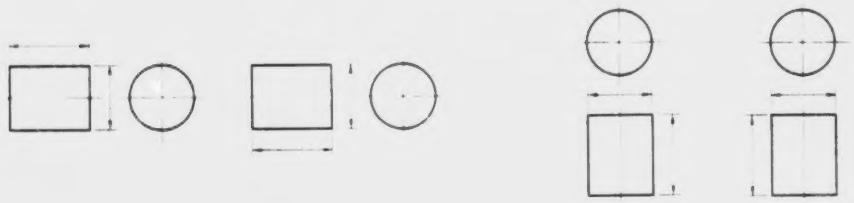
2. Size dimensions for geometric shapes

a. Prisms:

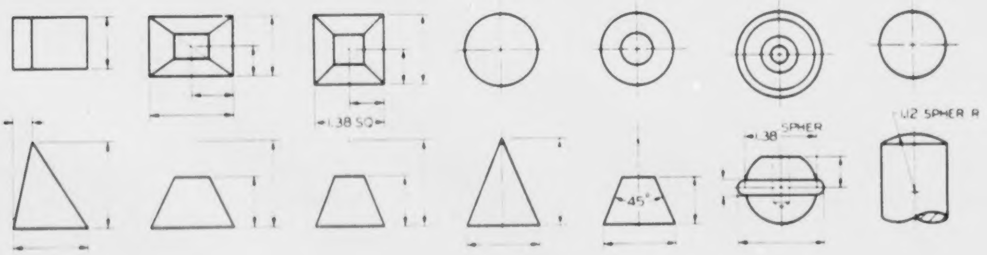


b. Cylinders:

Note: Diameter is not recommended for circular view but ANSI does approve its use.



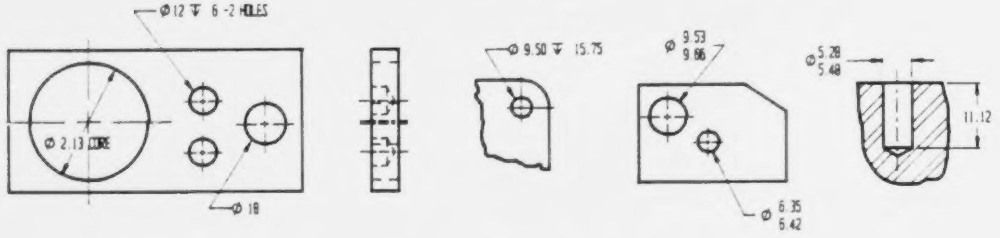
c. Miscellaneous shapes:


1.38 SQ
1.38 SPHER
1.12 SPHER R
45°

Information Sheet

d. Holes (negative cylinders):

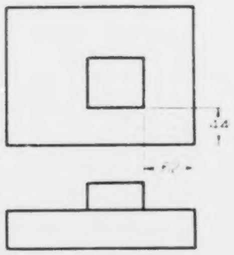
Note: These may be drilled, reamed, bored, punched, or cored as specified by standard notes.


⌀12 ↧ 6 -2 HOLES
⌀ 2.13 CORE
⌀ 18
⌀ 9.50 ↧ 15.75
⌀ 9.53 9.66
⌀ 6.35 6.42
⌀ 5.28 5.48
11.12

Note: Proportions of dimensioning symbols should be equal to the height (h) of the text (T); in other words, if T is .125, then h is .125. Refer to TMs 4 and 5.

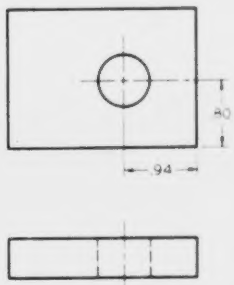
3. Location dimensions for geometric shapes

a. Rectangular shapes reference to their faces.



b. Cylinders or holes reference to their center lines.

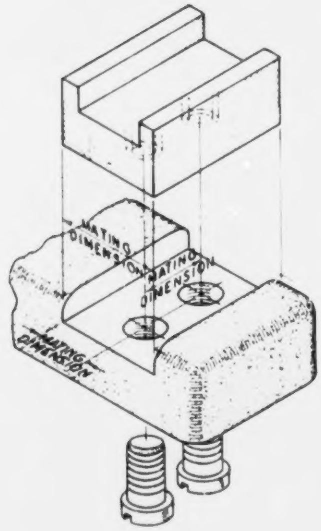
Note: Location dimensions are best located in circular view.

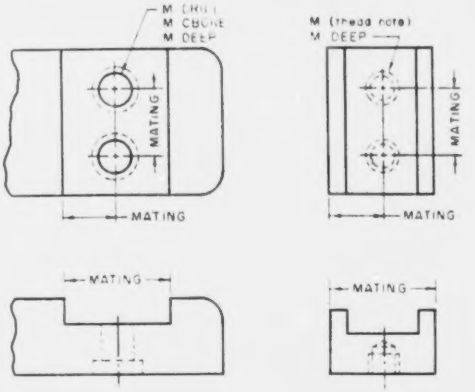


Information Sheet

4. Mating dimensions in an assembly drawing

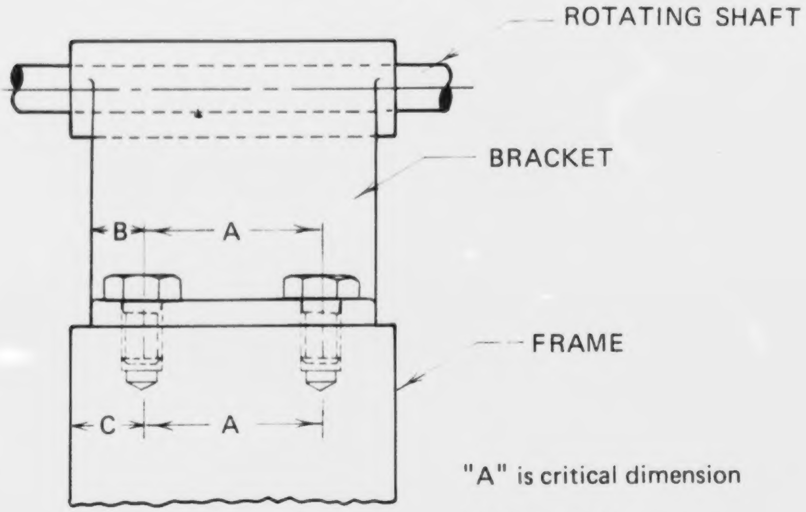
   a. Dimensions common to both parts are mating dimensions.


MATING DIMENSION
MATING DIMENSION
MATING DIMENSION


M DRILL
M CBORE
M DEEP
MATING
MATING
M (thread note)
M DEEP
MATING
MATING
MATING
MATING

   b. A single braket assembly has critical mating dimensions.

   Note: Critical dimension "A" of frame must mate critical dimension "A" of bracket. See following illustration.


ROTATING SHAFT
BRACKET
B
A
FRAME
C
A

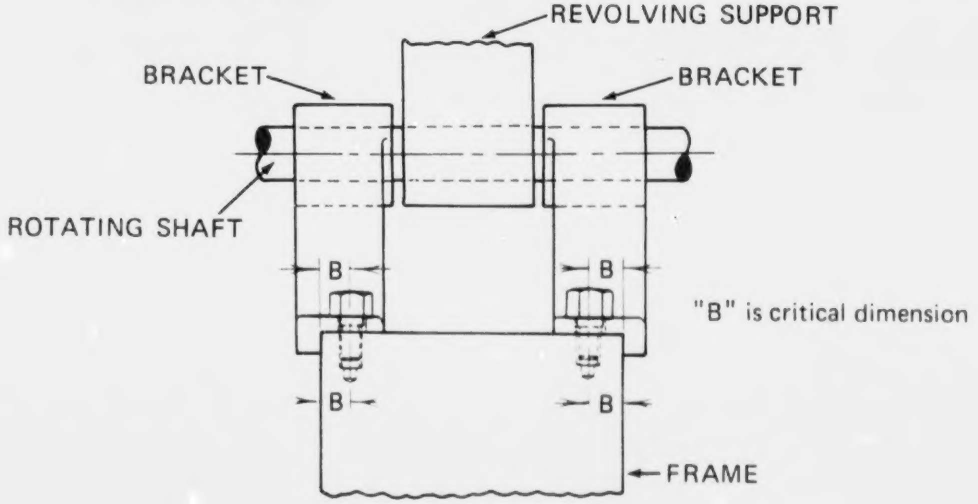
"A" is critical dimension

"B" and "C"
are not critical dimensions

Information Sheet

c. On a double bracket assembly has critical mating dimensions.

Note: With double bracket design, dimension "B" is critical dimension that must mate on both parts.


REVOLVING SUPPORT
BRACKET
BRACKET
ROTATING SHAFT
B
B
"B" is critical dimension
B
B
FRAME

5. Basic guidelines for numerical control dimensioning

a. Datum or reference planes must be selected that are mutually perpendicular in the X, Y, and Z axes.

b. Dimensions originate from the three planes.

c. Dimensions must be in decimals.

d. Angles should be in degrees and decimal parts of degrees.

e. Standard tools such as reamers, drills, and tapers should be specified wherever possible.

f. Tolerances should be used based on design requirements rather than tolerances of manufacturing machines.

Information Sheet

6. Fits for inch units and their applications

a. Fits for inch units may be running and sliding fits:

  (1) RC 1 (Close sliding fits)

  (2) RC 2 (Sliding fits)

  (3) RC 3 (Precision running fits)

  (4) RC 4 (Close running fits)

  (5) RC 5 - RC 6 (Medium running fits)

  (6) RC 7 (Free running fits)

  (7) RC 8 - RC 9 (Loose running fits)

b. Fits for inch units may be locational fits:

  (1) LC 1 - LC 11 (Locational clearance fits)

  (2) LT 1 - LT 6 (Transition fits)

  (3) LN 1 - LN 2 (Locational interference fits)

c. Fits for inch units may be force fits:

  (1) FN 1 (Light drive fits)

  (2) FN 2 (Medium drive fits)

  (3) FN 3 (Heavy drive fits)

  (4) FN 4 - FN 5 (Force fits)

Information Sheet

7. Fits for metric units (SI) and their applications

a. Fits for metric units may be clearance fits:

	HOLE BASIS	SHAFT BASIS
(1)	H11/c11	C11/h11 (Loose running fits)
(2)	H9/d9	D9/h9 (Free running fits)
(3)	H8/f7	F8/h7 (Close running fits)
(4)	H7/g6	G7/h6 (Sliding fits)
(5)	H7/h6	H7/h6 (Locational clearance fits)

b. Fits for metric units may be transition fits:

	HOLE	SHAFT
(1)	H7/k6	K7/h6 (Locational transition fits)
(2)	H7/n6	N7/h6 (Locational transition fits)

c. Fits for metric units may be interference fits:

	HOLE	SHAFT
(1)	H7/p6	P7/h6 (Locational interference fits)
(2)	H7/s6	S7/h6 (Medium drive fits)
(3)	H7/u6	U7/h6 (Force fits)

Information Sheet

8. Steps in calculating limits for clearance fit in inch units using the basic hole system

Tolerance Fit Table

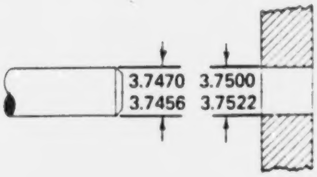
Nominal Size Range inches Over To	Class RC 5 Limits of Clearance	Class RC 5 Standard Limits Hole H8	Class RC 5 Standard Limits Shaft e7	Class RC 6 Limits of Clearance	Class RC 6 Standard Limits Hole H9	Class RC 6 Standard Limits Shaft e8	Class LT 3 Fit	Class LT 3 Standard Limits Hole H7	Class LT 3 Standard Limits Shaft k6	Class LT 4 Fit	Class LT 4 Standard Limits Hole H8	Class LT 4 Standard Limits Shaft k7
0 - 0.12	0.6 1.6	+0.6 -0	-0.6 -1.0	0.6 2.2	+1.0 -0	-0.6 -1.2						
0.12- 0.24	0.8 2.0	+0.7 -0	-0.8 -1.3	0.8 2.7	+1.2 -0	-0.8 -1.5						
0.24- 0.40	1.0 2.5	+0.9 -0	-1.0 -1.6	1.0 3.3	+1.4 -0	-1.0 -1.9	-0.5 +0.5	+0.6 -0	+0.5 +0.1	-0.7 +0.8	+0.9 -0	+0.7 +0.1
0.40- 0.71	1.2 2.9	+1.0 -0	-1.2 -1.9	1.2 3.8	+1.6 -0	-1.2 -2.2	-0.5 +0.6	+0.7 -0	+0.5 +0.1	-0.8 +0.9	+1.0 -0	+0.8 +0.1
0.71- 1.19	1.6 3.6	+1.2 -0	-1.6 -2.4	1.6 4.8	+2.0 -0	-1.6 -2.8	-0.6 +0.7	+0.8 -0	+0.6 +0.1	-0.9 +1.1	+1.2 -0	+0.9 +0.1
1.19- 1.97	2.0 4.6	+1.6 -0	-2.0 -3.0	2.0 6.1	+2.5 -0	-2.0 -3.6	-0.7 +0.9	+1.0 -0	+0.7 +0.1	-1.1 +1.5	+1.6 -0	+1.1 +0.1
1.97- 3.15	2.5 5.5	+1.8 -0	-2.5 -3.7	2.5 7.3	+3.0 -0	-2.5 -4.3	-0.8 +1.1	+1.2 -0	+0.8 +0.1	-1.3 +1.7	+1.8 -0	+1.3 +0.1
3.15- 4.73	3.0 6.6	+2.2 -0	-3.0 -4.4	3.0 8.7	+3.5 -0	-3.0 -5.2	-1.0 +1.3	+1.4 -0	+1.0 +0.1	-1.5 +2.1	+2.2 -0	+1.5 +0.1

Nominal Size Range inches Over To	Class FN 3 Limits of Interference	Class FN 3 Standard Limits Hole H7	Class FN 3 Standard Limits Shaft t6	Class FN 4 Limits of Interference	Class FN 4 Standard Limits Hole H7	Class FN 4 Standard Limits Shaft u6
0 - 0.12				0.3 0.95	+0.4 -0	+ 0.95 + 0.7
0.12- 0.24				0.4 1.2	+0.5 -0	+ 1.2 + 0.9
0.24- 0.40				0.6 1.6	+0.6 -0	+ 1.6 + 1.2
0.40- 0.56				0.7 1.8	+0.7 -0	+ 1.8 + 1.4
0.56- 0.71				0.7 1.8	+0.7 -0	+ 1.8 + 1.4
0.71- 0.95				0.8 2.1	+0.8 -0	+ 2.1 + 1.6
0.95- 1.19	0.8 2.1	+0.8 -0	+ 2.1 + 1.6	1.0 2.3	+0.8 -0	+ 2.3 + 1.8
1.19- 1.58	1.0 2.6	+1.0 -0	+ 2.6 + 2.0	1.5 3.1	+1.0 -0	+ 3.1 + 2.5
1.58- 1.97	1.2 2.8	+1.0 -0	+ 2.8 + 2.2	1.8 3.4	+1.0 -0	+ 3.4 + 2.8
1.97- 2.56	1.3 3.2	+1.2 -0	+ 3.2 + 2.5	2.3 4.2	+1.2 -0	+ 4.2 + 3.5

Basic hole system. Limits are in thousandths of an inch

From ANSI B4.1-1967(1987). With permission of ASME

Problem: Find limits for shaft and hole
Basic Size = 3.75
RC 5 Fit



Solution:

1. From tol fit table
   Hole + 2.2 Shaft -3.0
   - 0 -4.4
2. Hole
   3.7500 3.7500
   + .0022 - . 0
   3.7522 3.7500
3. Shaft
   3.7500 3.7500
   - .0030 - .0044
   3.7470 3.7456
4. Check Clearance
   Tightest fit MMC
   3.7500 Hole
   -3.7470 Shaft
   .0030
   Loosest fit LMC
   3.7522 Hole
   -3.7456 Shaft
   .0066
5. Check table under limits of fit

a. Refer to tolerance fit table for inch units, and locate basic hole size in Nomical size range, inches column.

Note: Limits are in thousandths of an inch. Multiply limit by .001 for calculations.

Example: Basic hole size **2.00** fit **RC 6** --Go to table--

Nominal size range, inches	Limits of clearance	Standards limits	
		Hole	Shaft
1.97-3.15	2.5 7.3	+3.0 - 0.	-2.5 -4.3

b. Calculate limits for the hole.

Example: 2.000 + 3.0(.001) = 2.003 Max. limit (LMC)—largest hole
2.000 - 0 = 2.000 Min. limit (MMC)—smallest hole

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c. Calculate limits for the shaft.

Example: 2.000 - 2.5(.001) = 1.9975 Max. limit (MMC)—largest shaft
2.000 - 4.3(.001) = 1.9957 Min. limit (LMC)—smallest shaft

d. Calculate allowance in inch units.

(1) Calculate tightest fit (MMC of hole—MMC of shaft)
smallest hole—largest shaft

Example: 2.000 - 1.9975 = .0025

(2) Look at table under limits of clearance and check your answer against table

Example: $\frac{.0025}{.001}$ = 2.5 which checks

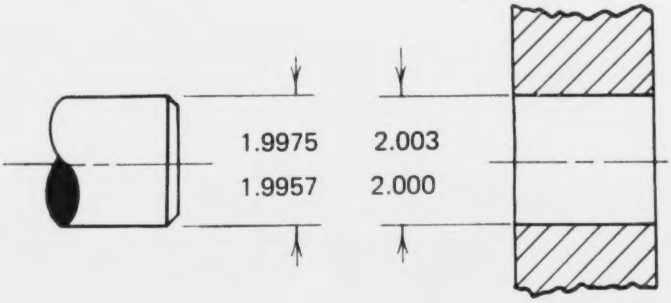
(3) Calculate loosest fit (LMC of hole—LMC of shaft)
largest hole—smallest shaft

Example: 2.0030 - 1.9957 = .0073

(4) Look at table under limits of clearance and check your answer against table

Example: $\frac{.0073}{.001}$ = 7.3 which checks

e. Dimension as indicated.



Information Sheet

9. **Steps in calculating limits for lcational fit in inch units using the basic hole system**

a. Refer to fit table for inch units, and locate basic hole size in Nominal size range, inches colum.

Example: Basic size **2.00** fit **LT 4** --Go to table--

b. Calculate limits for the hole.

Example: 2.00 + 1.8(.001) = 2.0018 LMC
2.00 - 0 = 2.0000 MMC

c. Calculate limits for the shaft.

Example: 2.00 + 1.3(.001) = 2.0013 MMC
2.00 + .1(.001) = 2.0001 LMC

d. Calculate fit.

(1) Calculate tightest fit (MMC of hole—MMC of shaft).

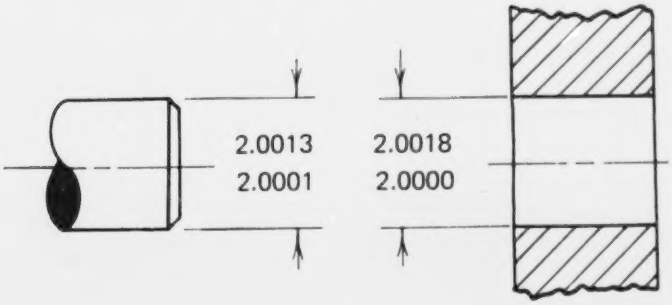
Example: 2.0000 - 2.0013 = -.0013

(2) Calculate loosest fit (LMC of hole—LMC of shaft).

Example: 2.0018 - 2.0001 = +.0017

(3) Check table under fit to check your answer.

e. Dimension as indicated.



Information Sheet

10. Steps in calculating limits for force fit in inch units using the basic hole system

a. Refer to fit table for inch units, and locate basic hole size in Nominal size range, inches column.

Example: Basic size **2.00** fit **FN 3** --Go to table--

b. Calculate limits for the hole.

Example: 2.00 + (1.2)(.001) = 2.0012 LMC
2.00 - 0 = 2.0000 MMC

c. Calculate limits for the shaft.

Example: 2.00 + 3.2(.001) = 2.0032 MMC
2.00 + 2.5(.001) = 2.0025 LMC

d. Calculate limits of interference.

(1) Calculate tightest interference (MMC of hole—MMC of shaft).

Example: 2.0000 - 2.0032 = -.0032

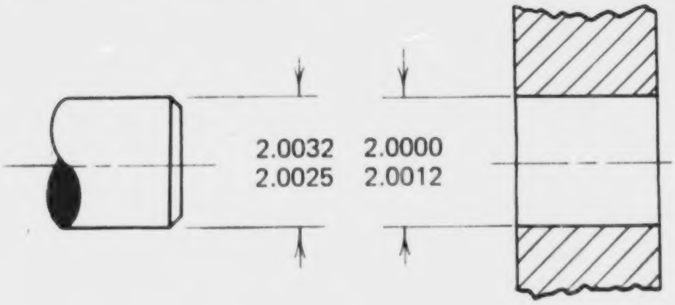
(2) Calculate loosest interference (LMC of hole—LMC of shaft).

Example: 2.0012 - 2.0025 = -.0013

Note: Notice both have negative values.

(3) Check table under limits of interference to check you answer.

e. Dimension as indicated.



Information Sheet

11. Steps in calculating limits in inch units using the basic shaft size system

a. Refer to fit table for inch units, and locate the basic shaft size.

Example: Basic shaft size **2.00** fit **RC 6** --Go to table--

Nominal size range, inches	Limits of clearance	Standards limits	
		Hole	Shaft
1.97-3.15	2.5 7.3	+3.0 - 0.	-2.5 -4.3

b. Calculate basic hole size by adding allowance at MMC to basic shaft size.

Example: 2.000 + .0025 = 2.0025 basic hole size

Note: Now use table as we did in basic hole system.

c. Calculate limits for the hole.

Example: 2.0025 + 3.0(.001) = 2.0055 LMC
2.0025 - 0 = 2.0025 MMC

d. Calculate limits for the shaft.

Example: 2.0025 - 2.5(.001) = 2.0000 MMC
2.0025 - 4.3(.001) = 1.9982 LMC

e. Calculate allowance.

(1) Calculate tightest fit (MMC of hole—MMC of shaft).

Example: 2.0025 - 2.0000 = .0025

(2) Check allowance from table.

(3) Calculate loosest fit (LMC of hole—LMC of shaft)

Example: 2.0055 - 1.9982 = .0073

(4) Check allowance from table

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12. Steps in calculating limits for clearance fit in metric units using the basic hole system

Tolerance
Fit
Table

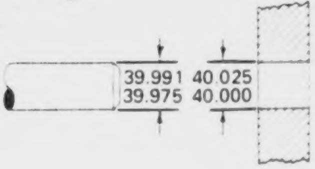
Clearance Fits, Hole Basis

BASIC SIZE		LOOSE RUNNING			FREE RUNNING			CLOSE RUNNING			SLIDING			LOCATIONAL CLEARANCE		
		Hole H11	Shaft c11	Fit	Hole H9	Shaft d9	Fit	Hole H8	Shaft f7	Fit	Hole H7	Shaft g6	Fit	Hole H7	Shaft h6	Fit
40	MAX	40.160	39.880	0.440	40.062	39.920	0.204	40.039	39.975	0.089	40.025	39.991	0.050	40.025	40.000	0.041
	MIN	40.000	39.720	0.120	40.000	39.858	0.080	40.000	39.950	0.025	40.000	39.975	0.009	40.000	39.984	0.000
50	MAX	50.160	49.870	0.450	50.062	49.920	0.204	50.039	49.975	0.089	50.025	49.991	0.050	50.025	50.000	0.041
	MIN	50.000	49.710	0.130	50.000	49.858	0.080	50.000	49.950	0.025	50.000	49.975	0.009	50.000	49.984	0.000
60	MAX	60.190	59.860	0.520	60.074	59.900	0.248	60.046	59.970	0.106	60.030	59.990	0.059	60.030	60.000	0.049
	MIN	60.000	59.670	0.140	60.000	59.826	0.100	60.000	59.940	0.030	60.000	59.971	0.010	60.000	59.981	0.000
80	MAX	80.190	79.850	0.530	80.074	79.900	0.248	80.046	79.970	0.106	80.030	79.990	0.059	80.030	80.000	0.049
	MIN	80.000	79.660	0.150	80.000	79.826	0.100	80.000	79.940	0.030	80.000	79.971	0.010	80.000	79.981	0.000
100	MAX	100.220	99.830	0.610	100.087	99.880	0.294	100.054	99.964	0.125	100.035	99.988	0.069	100.035	100.000	0.057
	MIN	100.000	99.610	0.170	100.000	99.793	0.120	100.000	99.929	0.036	100.000	99.966	0.012	100.000	99.978	0.000
120	MAX	120.220	119.820	0.620	120.087	119.880	0.294	120.054	119.964	0.125	120.035	119.988	0.069	120.035	120.000	0.057
	MIN	120.000	119.600	0.180	120.000	119.793	0.120	120.000	119.929	0.036	120.000	119.966	0.012	120.000	119.978	0.000
160	MAX	160.250	159.790	0.710	160.100	159.855	0.345	160.063	159.957	0.146	160.040	159.986	0.079	160.040	160.000	0.065
	MIN	160.000	159.540	0.210	160.000	159.755	0.145	160.000	159.917	0.043	160.000	159.961	0.014	160.000	159.975	0.000

(NOTE: Dimensions are in mm.)

From ANSI B4.2-1978(1984) With permission of ASME

Problem:
Find limits for shaft and hole
Basic Size = 40mm
Fit H7/g6



Solution:

1. From tol fit tables, locate 40mm basic size
2. Hole limits
   H7 40.025 LMC (Max hole)
   40.000 MMC (Min hole)
3. Shaft limits
   g6 39.991 MMC (Max shaft)
   39.975 LMC (Min shaft)
4. Check Clearance
   Tightest fit MMC
   40.000 Hole
   -39.991 Shaft
   .009
   Loosest fit LMC
   40.025 Hole
   -39.975 Shaft
   .050
5. Check table under limits of fit

a. Refer to fit table for metric units, and locate basic size in Basic Size column.

Example: Basic hole size **40mm** fit **H7/g6** --Go to fit table--

Basic Size	Hole H7	Shaft g6	Fit
40 Max. Min.	40.025 40.000	39.991 39.975	0.050 0.009

b. Read from table hole limits.

Example: H7 40.025 maximum hole LMC
H7 40.000 minimum hole MMC

c. Read from table shaft limits.

Example: g6 39.991 maximum shaft MMC
g6 39.975 minimum shaft LMC

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d. Calculate allowance.

(1) Calculate tightest fit (MMC of hole—MMC of shaft).
smallest hole—largest shaft

Example: 40.000 - 39.991 = .009

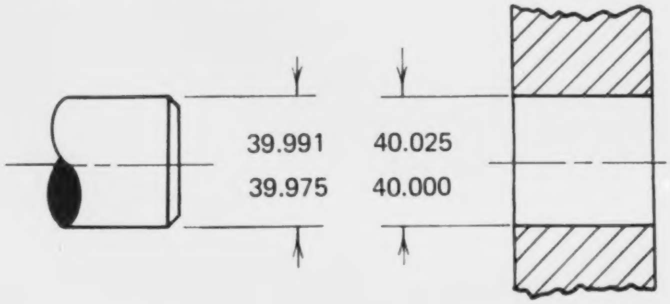
(2) Check table under minimum fit to check this calculation.

(3) Calculate loosest fit (LMC of hole—LMC of shaft).
largest hole—smallest shaft

Example: 40.025 - 39.975 = .050

(4) Check table under maximum fit to check this calculation.

e. Dimension as indicated.



13. Steps in calculating limits for transition fit in metric units using the basic hole system

a. Refer to fit table for metric units (SI), and locate basic size in Basic Size column.

Example: Basic size **40mm** fit **H7/k6** --Go to table--

b. Read from table hole limits.

Example: H7 40.025 LMC
H7 40.000 MMC

c. Read from table shaft limits.

Example: k6 40.018 MMC
k6 40.002 LMC

d. Calculate fit.

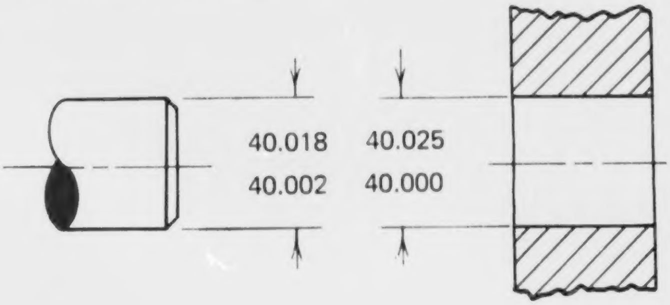
(1) Calculate tightest fit (MMC of hole—MMC of shaft).

Example: 40.000 - 40.018 = -.018

(2) Calculate loosest fit (LMC of hole—LMC of shaft).

Example: 40.025 - 40.002 = +.023

e. Dimension as indicated.



14. Steps in calculating limits for interference in fit metric units using the basic hole system

a. Refer to fit table for metric units (SI), and locate basic size in Basic Size column.

Example: Basic size **50mm** fit **H7/u6** --Go to table--

b. Read from table hole limits.

Example: H7 50.025 LMC
H7 50.000 MMC

c. Read from table shaft limits.

Example: u6 50.086 MMC
u6 50.070 LMC

d. Calculate allowance.

(1) Calculate tightest fit (MMC of hole—MMC of shaft).

Example: 50.000 - 50.086 = -.086

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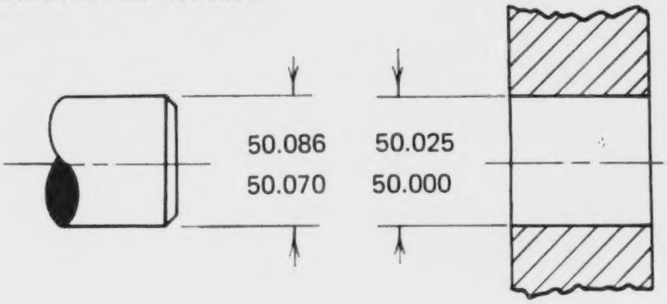
(2) Calculate loosest fit (LMC of hole—LMC of shaft).

Example: 50.025 - 50.070 = +.045

e. Dimension as indicated.



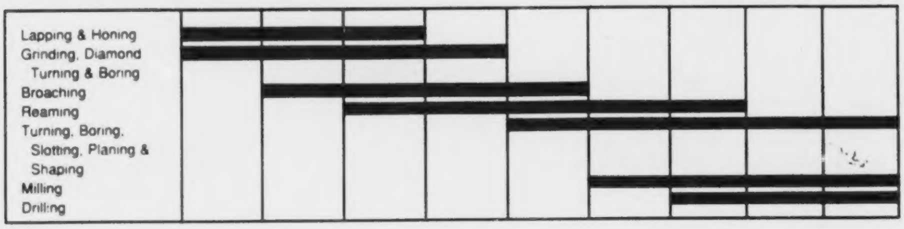
15. Tolerance ranges and their relationship to costs and shop processes

a. Shop processes are those processes that use various equipment and procedures to shape or finish a component.

b. Basic shop processes include grinding, broaching, reaming, and boring.

c. Other shop processes include slotting, planing, turning, and diamond turning for working with hard compounds or products.

Range of Size From	To & Inc	Tolerances								
000	599	00015	0002	0003	0005	0008	0012	002	003	005
600	999	00015	00025	0004	0006	001	0015	0025	004	006
1 000	1 499	0002	0003	0005	0008	.0012	002	003	005	008
1 500	2 799	00025	0004	0006	001	.0015	0025	004	006	010
2.800	4 499	0003	0005	0008	0012	002	003	005	008	012
4 500	7 799	0004	0006	001	0015	0025	.004	006	010	015
7 800	13 599	0005	0008	0012	002	003	005	008	012	020
13 600	20 999	0006	001	0015	0025	004	006	010	015	025



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d. Since lapping and honing produce the smallest tolerances, they are the most expensive of the shop processes.

e. Since milling and drilling produce the largest tolerances, they are the least expensive of the shop processes, and are the shop processes used the most.

16. Guidelines for determining clearance fit on standard dowels

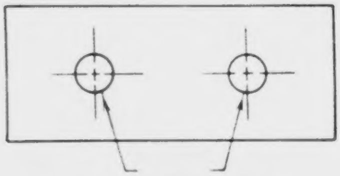
a. When the limits of clearance are given:

(1) The tightest fit = MMC hole - MMC shaft.

(2) The loosest fit = LMC hole - LMC shaft.

.2515
.2507
Tightest Fit = MMC of Hole - MMC of Shaft
.0005 = MMC of Hole - .2502
.2507 = MMC of Hole

Loosest Fit = LMC of Hole - LMC of Shaft
.0015 = LMC of Hole - .2500
.2515 = LMC of Hole



Dowel .2502 MMC
.2500 LMC
RC 3 Fit
Limits of
Clearance
.0005, - .0015

b. Limits of clearance: smallest number is tightest fit; largest number is loosest fit.

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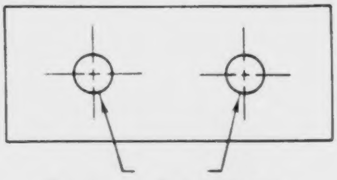
17. Guidelines for determining interference fit on standard dowels

a. When the limits of interference are given:

(1) The tightest fit = MMC hole - MMC shaft.

(2) The loosest fit = LMC hole - LMC shaft.



Dowel .2502 MMC
.2500 LMC
FN2 - Fit
Limits of
Interference
.0004, - .0014

.2496
.2488
Tightest Fit = MMC of Hole - MMC of Shaft
-.0014 = MMC of Hole - .2502
.2488 = MMC of Hole

Loosest Fit = LMC of Hole - LMC of Shaft
-.0004 = LMC of Hole - .2500
.2496 = LMC of Hole

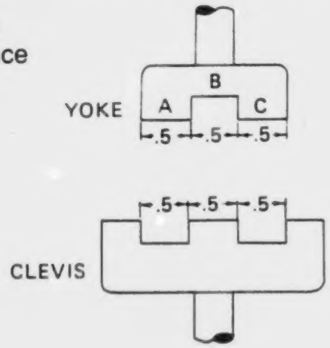
b. Limits of interference: largest number is the tightest fit and is negative; smallest number is the loosest fit and is negative.

18. Guidelines for determining limit dimensions for the interchangability of parts

Note: A basic rule in mechanical drafting is that when function is not affected, parts should be toleranced to fit end-for-end to make assembly faster and easier.

a. Find limit dimensions of each part and dimension so parts fit end-for-end.

Example: Nominal size .500; .004 maximum accumulation of tolerance; clearance between each mating part .005; loosest fit not to exceed .015



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b. Since parts must fit end-for-end, the limit dimensions must be the same on both ends.

c. Select the center dimension to be basic size.

Note: It could be yoke or clevis. Yoke was selected for the following example.

Example:	Yoke (B) MMC	.500
	clearance	-.005
	Clevis (B) MMC	.495

d. Distribute maximum accumulation equally on each side of parts.

Note: As you can see in the following example, 3 does not divide into .004 evenly, so we give .002 to the center (B) and .001 to both sides A and C.)

Example:	.002	tolerance distribution
	.001	tolerance distribution
	.001	tolerance distribution
	.004	maximum accumulation

e. Calculate LMC for center (B).

Example:	Yoke (B) MMC	.500	
	(B) Tol.	+.002	
	Yoke (B) LMC	.502	
	Clevis (B) MMC	.495	
	(B) Tol.		-.002
	Clevis (B) LMC	.493	

Note: The + and - signs are for LMC; that is, if a feature is like a hole, LMC is "+"; if a feature is like a shaft, it is "-".

f. Calculate MMC for sides (A or C).

(1) Use LMC of yoke (B) for LMC of clevis (A) or (C).

Example:	Clevis (A) or (C) LMC	.502
	Tol. dist.	-.001
	Clevis (A) or (C) MMC	.501

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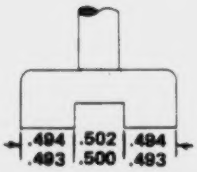
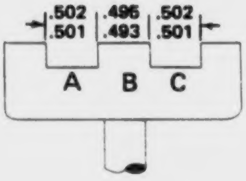
(2) Use LMC of clevis (B) for LMC of yoke (A) or (C).

Example:		
	Yoke (A) or (C) LMC	.493
	Tol. dist.	+.001
	Yoke (A) or (C) MMC	.494





g. When each part is toleranced, an accumulation of tolerance must be checked.

(1) Add up maximum and minimum values.

Example:

Max. of yoke	Min. of yoke
.494	.493
.502	.500
.494	.493
1.490	1.486

Max. of clevis	Min. of clevis
.502	.501
.495	.493
.494	.501
1.499	1.495

(2) Subtract minimum of each part from the maximum of mating part.

Example: Max. of yoke - Min. of clevis = clearance (overall)
Max. of cleavis - Min. of yoke = loosest fit

1.490 - 14.95 = .005 (checks for clearance)
1.499 - 1.486 = .013 (checks within loosest fit)

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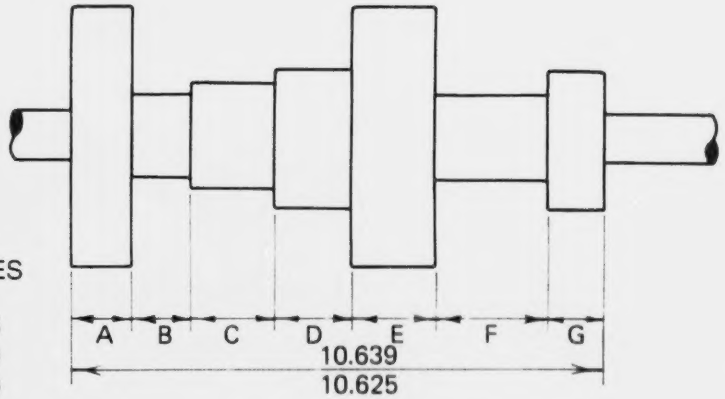
19. Steps for determining limit dimensions for intermediate parts to retain overall limits

Note: Always use largest possible tolerance.

a. Find limit dimensions.

Example:



BASIC SIZES

A	1.375
B	1.250
C	1.750
D	1.500
E	1.750
F	2.000
G	1.000

b. Subtract upper and lower limits of overall dimension to get total tolerance accumulation.

Example: 10.639 - 10.625 = .014 total tolerance accumulation

c. Divide total tolerance accumulation by number of toleranced parts to get tolerance per part.

Example: $\frac{.014}{7}$ = .002 tolerance per part

d. Add tolerance per part to each basic size to get upper limit of each part.

Example:

$$\begin{array}{rrrr} 1.375 & 1.250 & 1.750 & 1.500 \\ \underline{+\ .002} & \underline{+\ .002} & \underline{+\ .002} & \underline{+\ .002} \\ 1.377 & 1.252 & 1.752 & 1.502 \end{array}$$

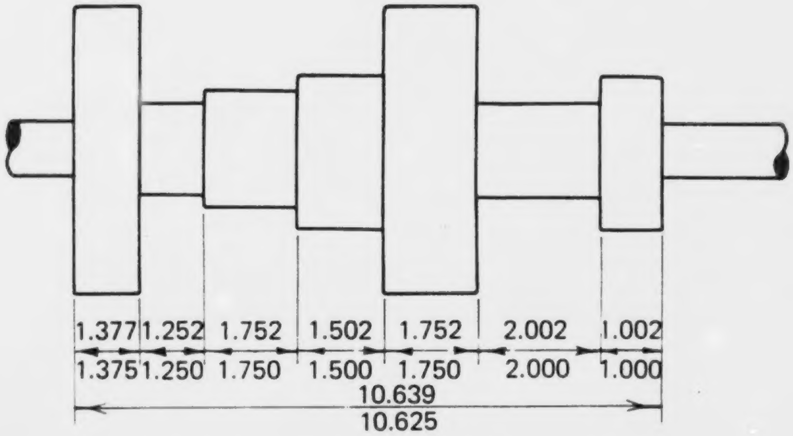
$$\begin{array}{rrr} 1.750 & 2.000 & 1.000 \\ \underline{+\ .002} & \underline{+\ .002} & \underline{+\ .002} \\ 1.752 & 2.002 & 1.002 \end{array}$$

Note: The lower limit is basic size.

Information Sheet

e. Check by adding upper limits together to get upper limit of overall dimension.

Example: 1.377 + 1.252 + 1.752 + 1.502 + 1.752 + 2.002 + 1.002 = 10.639


1.377
1.375
1.252
1.250
1.752
1.750
1.502
1.500
1.752
1.750
2.002
2.000
1.002
1.000
10.639
10.625

20. ANSI and ISO symbols for tolerances of position and form

SYMBOL FOR:	ANSI Y14.5
STRAIGHTNESS	—
FLATNESS	▱
CIRCULARITY	○
CYLINDRICITY	⌭
PROFILE OF A LINE	⌒
PROFILE OF A SURFACE	⌓
ALL AROUND–PROFILE	←⊖
ANGULARITY	∠
PERPENDICULARITY	⊥
PARALLELISM	//
POSITION	⌖
CONCENTRICITY/COAXIALITY	◎
SYMMETRY	NONE
CIRCULAR RUNOUT	↗
TOTAL RUNOUT	⌰

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Information Sheet

21. ANSI and ISO modifying symbols and terms for tolerances of position and form

SYMBOL FOR:	ANSI Y14.5
AT MAXIMUM MATERIAL CONDITION	Ⓜ
AT LEAST MATERIAL CONDITION	Ⓛ
REGARDLESS OF FEATURE SIZE	Ⓢ
PROJECTED TOLERANCE ZONE	Ⓟ
DIAMETER	Ø
BASIC DIMENSION	$\boxed{50}$
REFERENCE DIMENSION	(50)
DATUM FEATURE	$\boxed{-A-}$
DATUM TARGET	Ø6 A1
TARGET POINT	×
DIMENSION ORIGIN	⌽→
FEATURE CONTROL FRAME	⌖ Ø0.5Ⓜ A B C
CONICAL TAPER	⌲
SLOPE	⌳
COUNTERBORE/SPOTFACE	⌴
COUNTERSINK	⌵
DEPTH/DEEP	↧
SQUARE (SHAPE)	□
DIMENSION NOT TO SCALE	$\underline{15}$
NUMBER OF TIMES/PLACES	8X
ARC LENGTH	$\overset{\frown}{105}$
RADIUS	R
SPHERICAL RADIUS	SR
SPHERICAL DIAMETER	SØ

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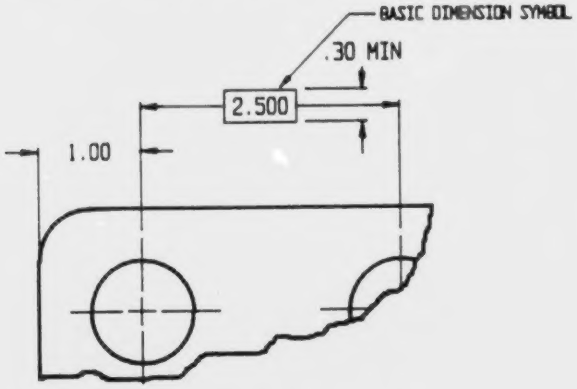
Information Sheet

22. Position and form symbols

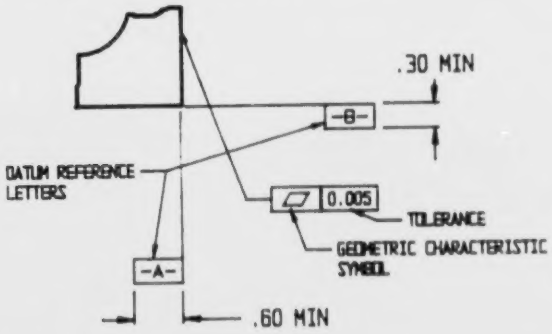
a. Position and form symbols are critical in mechanical drafting because they include a basic dimension symbol, a datum symbol, and a datum reference.

b. Feature control symbols are critical because they show:

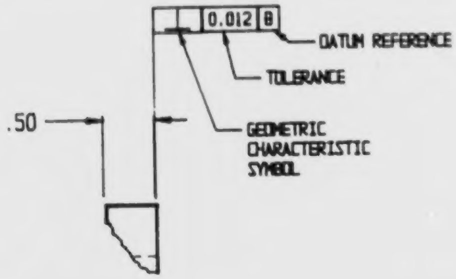
(1) The basic dimension symbol;


BASIC DIMENSION SYMBOL
.30 MIN
2.500
1.00

(2) The geometric characteristic symbol;

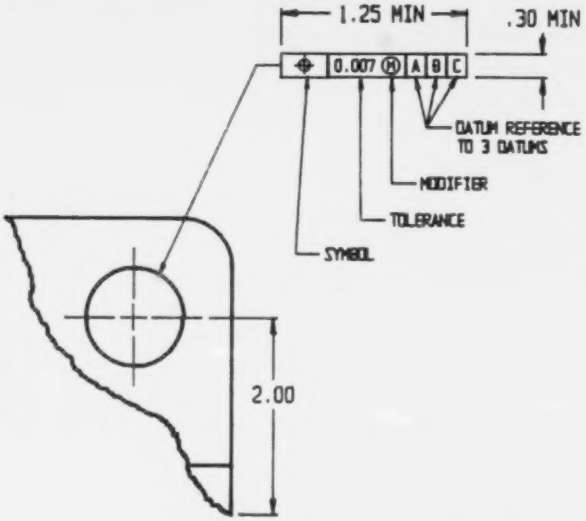

.30 MIN
-B-
DATUM REFERENCE LETTERS
0.005
TOLERANCE
GEOMETRIC CHARACTERISTIC SYMBOL
-A-
.60 MIN

(3) The datum and tolerance reference.

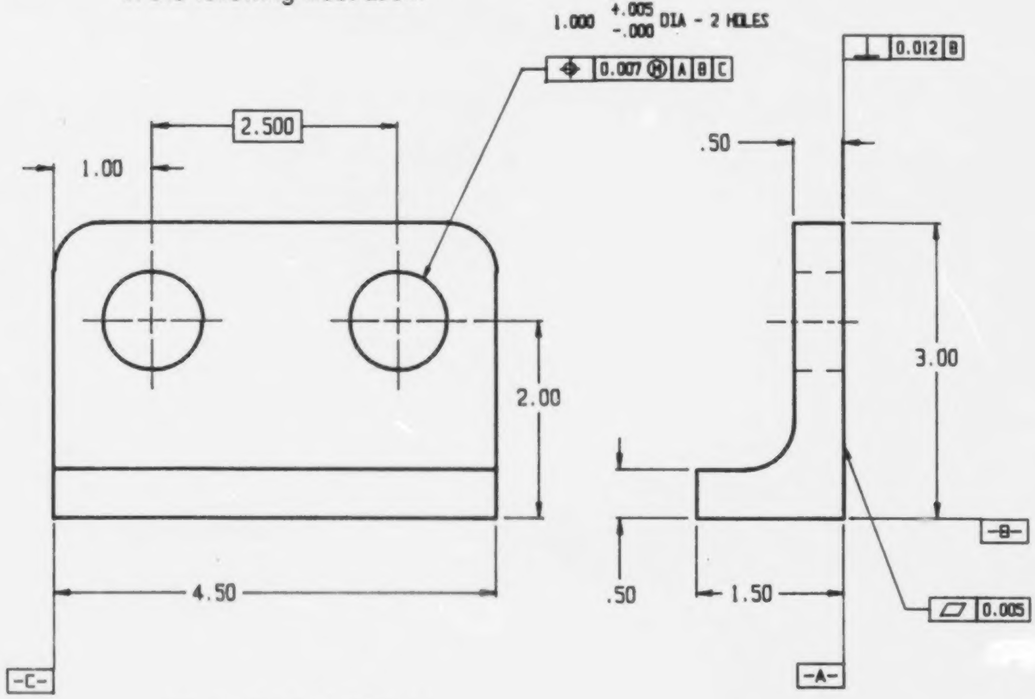

0.012
B
DATUM REFERENCE
TOLERANCE
GEOMETRIC CHARACTERISTIC SYMBOL
.50

Information Sheet

c. Feature control symbols include the symbol, datum references for one or two datums, tolerance, and a modifier of datum and of tolerance.


1.25 MIN
.30 MIN
⌖ 0.007 Ⓜ A B C
DATUM REFERENCE TO 3 DATUMS
MODIFIER
TOLERANCE
SYMBOL
2.00

d. Symbols for position and form are applied in tolerance dimensions as indicated in the following illustration.


1.000 +.005 -.000 DIA - 2 HOLES
⌖ 0.007 Ⓜ A B C
⊥ 0.012 B
2.500
1.00
.50
3.00
2.00
-B-
4.50
.50
1.50
▱ 0.005
-C-
-A-

NOTE: ALL FILLETS AND ROUNDS .5 R

Information Sheet

23. Descriptions of position and form

a. Basic descriptions of position and form include straightness, flatness, roundness, and cylindricity.

b. A description may have no specified tolerance of form.

c. Profile descriptions concern the profile of a surface, or the profile of a surface between points.

d. Descriptions for orientation concern angularity, perpendicularity, parallelism, and symmetry.

e. Descriptions for location involve position and concentricity.

24. Positional tolerancing

a. Positional tolerancing depends on the type of zone; in conventional limit location dimensions, the tolerance zone is square, but positional tolerancing allows for a circular zone.

b. In cylindrical tolerance zones, positional tolerancing allows more tolerance than conventional limit dimensions.

c. Tolerance accumulation is not allowed in positional tolerancing.

d. Positional tolerancing does permit variations, such as the extreme angular variation for drilling a hole.

25. Features of MMC (maximum material condition) and RFS (regardless of feature size)

a. MMC is less restrictive.

b. RFS is more restrictive.

26. Angular tolerances

a. Bilateral angular tolerances cause a larger tolerance zone when moving from the vertex.

b. Because of the use of angular feature controls, basic angular tolerances cause a parallel tolerance zone.

27. Surface quality specifications, symbols, and symbol placement

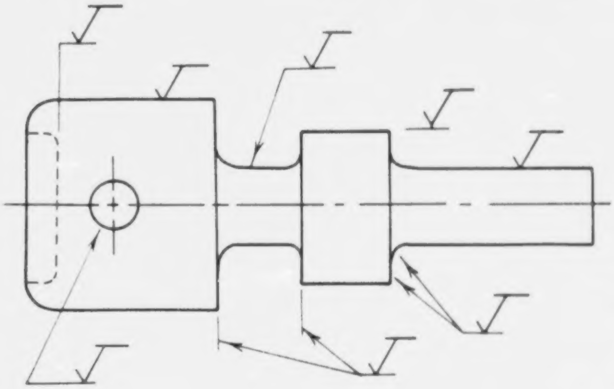
a. Surface quality specifications are used in the aerospace, automotive, or aircraft industries where conditions of heavy loads and high speeds require less friction.

Information Sheet

b. Parts of a surface quality symbol may include roughness of height, roughness of width, waviness of height, or vaviness of width.

c. Other parts of a surface quality symbol could include roughness width cutoff, or lay which means disposition in relation to the surface such as parallel to or angular to the surface.

d. Place surface quality symbols on the edge of a surface and read the symbols from the bottom of the sheet. (Note typical placement in the following graphic.)



28. Surface quality notes

a. Surface quality notes are dedicated to helping achieve an important manufacturing objective: to provide the roughest surface that will satisfy function and form.

b. Values in notes are expressed in micrometers or microinches, and the higher the micrometer or microinch, the rougher the surface.

c. The quality symbol is always made in the standard upright position.

29. Lay sumbols and their meanings

a. = — Parallel to surface

b. ⊥ — Perpendicular to surface

c. X — Angular to surface

d. M — Multidirectional

e. C — Circular

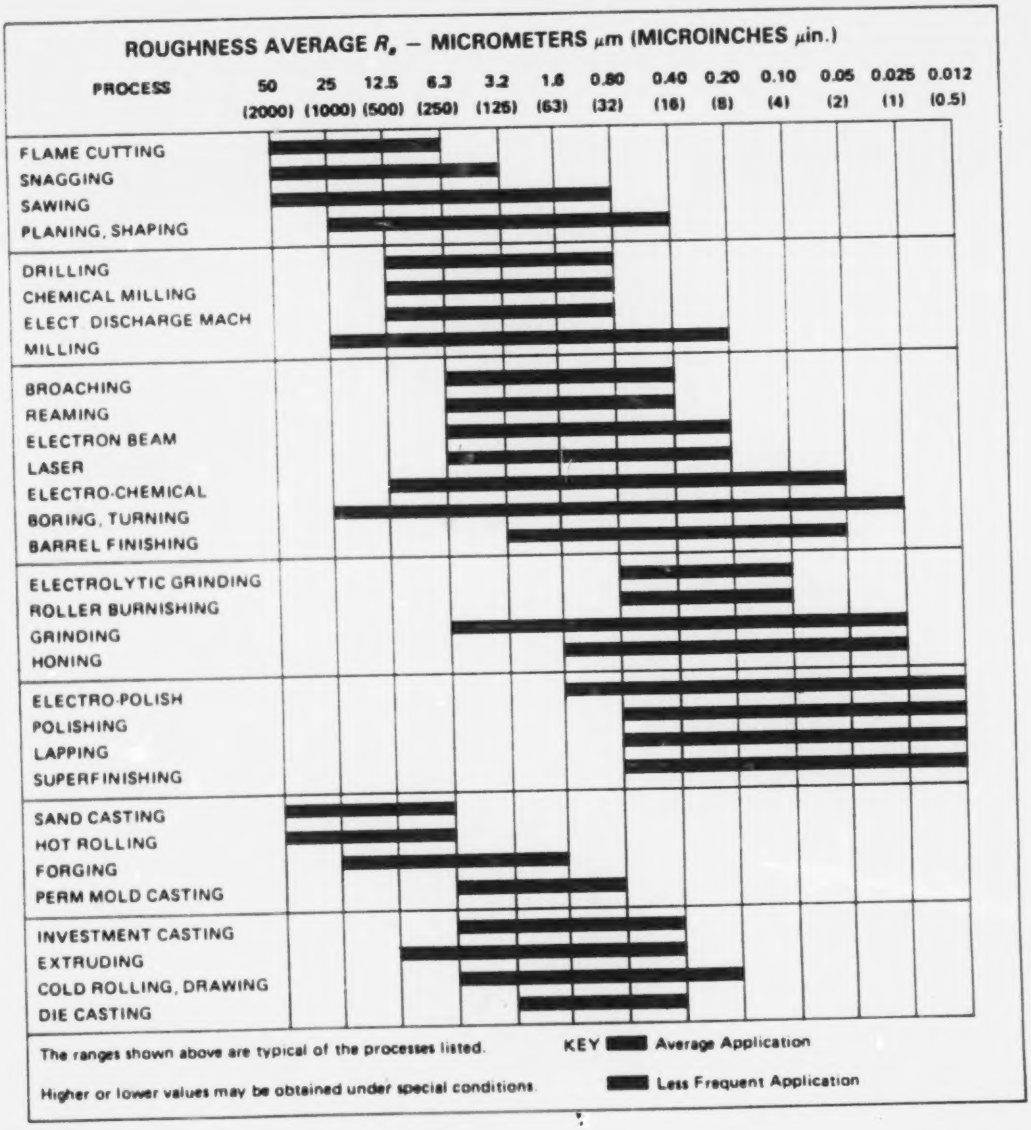
f. R — Radial

g. p^3 — Particulate, nondirectional, or protuberant

Information Sheet

30. Production processes and degrees of surface roughness they produce

Note: In the following chart, microinches are indicated parenthetically.



The ranges shown above are typical of the processes listed.

Higher or lower values may be obtained under special conditions.

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Information Sheet

31. Recommended values for surface quality roughness

Note: In the following charts, microinches are indicated parenthetically.

Roughness average rating values—Preferred values in boldface type

Recommended Rouchness
Average Rating Values
Micrometers (Microinches)

µm	µin.	µm	µin.
0.025	(1)	1.25	(50)
0.050	**(2)**	**1.6**	**(63)**
0.075	(3)	2.0	(80)
0.100	**(4)**	2.5	(100)
0.125	(5)	**3.2**	**(125)**
.015	(6)	4.0	(160)
.020	**(8)**	5.0	(200)
.025	(10)	**6.3**	**(250)**
.032	(13)	8.0	(320)
.040	**(16)**	10.0	(400)
.050	(20)	**12.5**	**(500)**
0.63	(25)	15.0	(600)
.080	**(32)**	20.0	(800)
1.00	(40)	25.0	(1000)

- Waviness height values—Preferred values in boldface type

Recommended Waviness
Height Values,
Millimeters (Inches)

mm	in.	mm	in.
0.0005	**(.00002)**	**0.025**	**(.0010)**
0.008	(.00003)	**0.05**	**(.002)**
0.0012	**(.00005)**	0.08	(.003)
0.0020	(.0008)	**0.12**	**(.005)**
0.0025	**(.00010)**	0.20	(.008)
0.005	**(.0002)**	**0.25**	**(.010)**
0.008	(.0003)	0.38	(.015)
0.012	**(.0005)**	**0.50**	**(.020)**
0.020	(.0008)	0.80	(.030)

Information Sheet

Roughness width cutoff values—Preferred values in boldface type

Recommended
Standard Roughness
Width Cutoff Values
Millimeters (Inches)

mm	in.	mm	in.
0.08	(0.03)	2.50	(.100)
0.25	(.013)	8.0	(.300)
0.80	**(.030)**	25.0	(1.000)

32. Advantages of using CAD for dimensioning and tolerancing

a. CAD systems use ANSI and ISO standards to provide the CAD operator with automatic symbol generation for ease of placement and parametric input.

b. CAD automatically generates dimensioning, tolerancing, and surface symbols.

c. CAD provides standard tolerances and standard dimensions for spacing offsets.

d. CAD provides arrowheads that are uniform in type and size.

e. CAD provides standard symbols and figures.

f. CAD provides standard notes and title blocks.

g. CAD provides standard form and position tolerances.

Dimensioning and Tolerancing
Unit 4

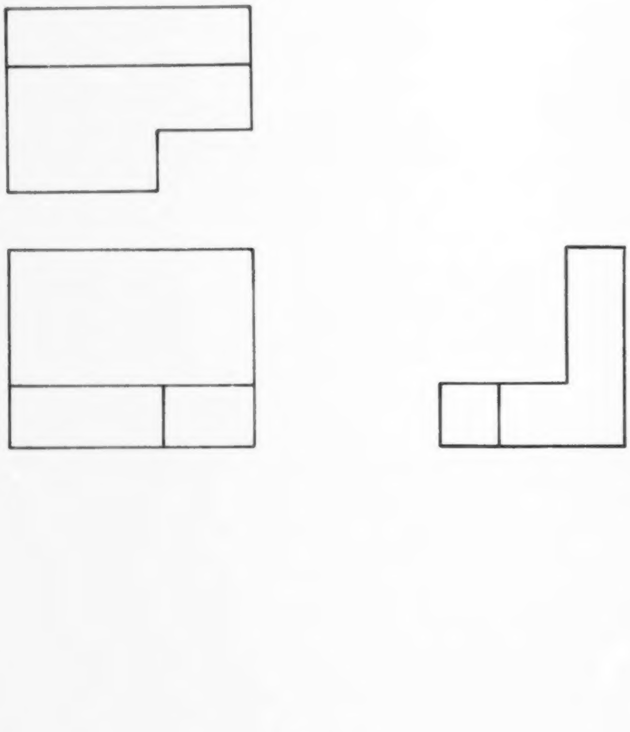
Assignment Sheet 1—Dimension an Object Completely

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Full size dimensions completed	______
Half size metric dimensions completed	______
¼″ = 1″ dimensions completed	______
Neatness and general appearance	______

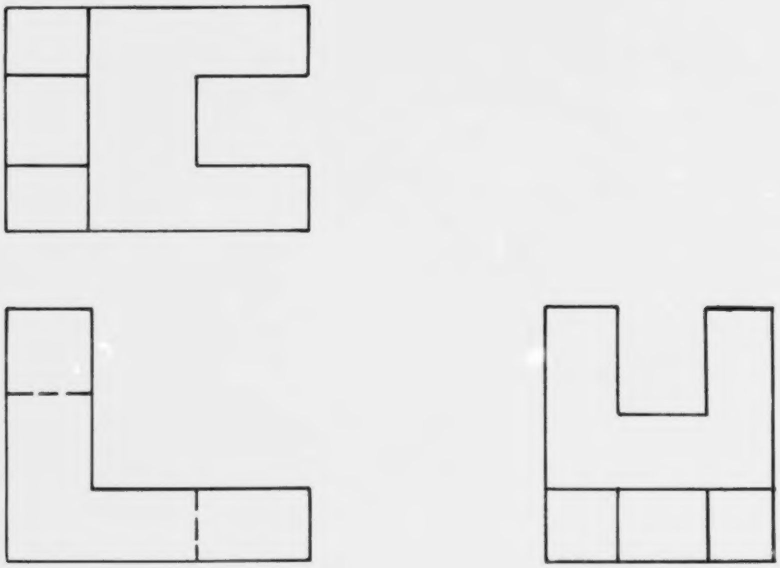
Directions: With drafting tools and machine, dimension the following objects using proper dimensioning rules and techniques.

A. Full size - inch system - fractions

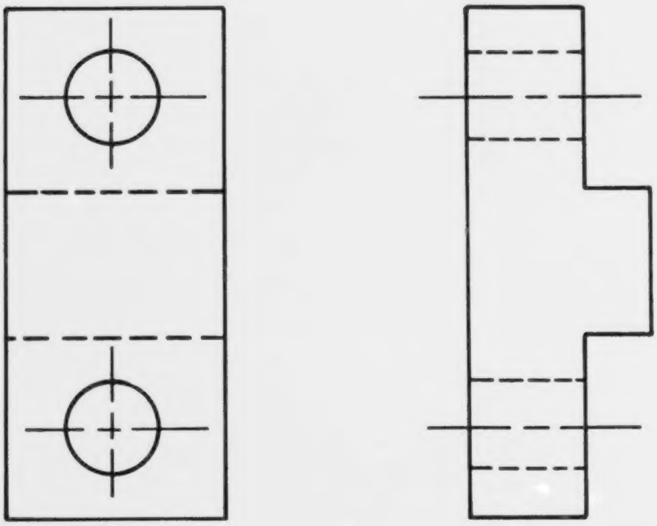


Assignment Sheet 1

B. Half size - metric system



C. ¼" = 1" - inch system - decimal



Dimensioning and Tolerancing
Unit 4

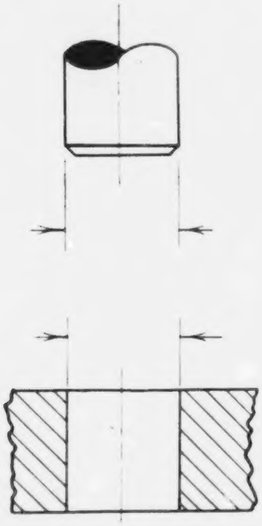
Assignment Sheet 2—Calculate and Dimension Clearance Fit Tolerances using Standard Fit Tables

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Inch system dimensions completed	______
Metric system dimensions completed	______
Neatness and appearance	______

Directions: Calculate and dimension the following clearance fit tolerances using standard fit tables.

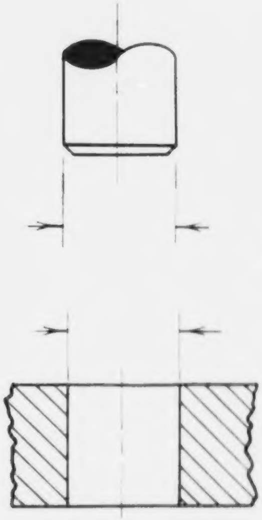
A. Inch system using ANSI B 4.1 - 1967, R 1987



Fit RC 4

Basic Size 1.00

Check fit



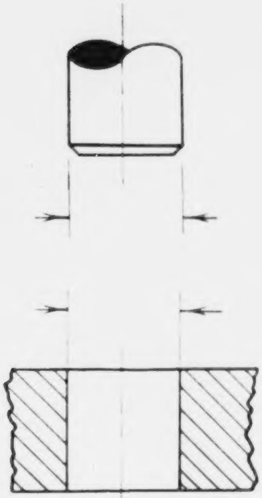
Fit RC 2

Basic Size 2.50

Check fit

Assignment Sheet 2

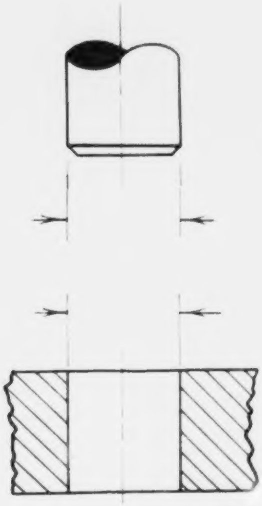
B. Metric system using ANSI B 4.2 - 1984



Fit H7/g6

Basic Size 40

Check fit



Fit D9/h9

Basic Size 2.5

Check fit

Dimensioning and Tolerancing
Unit 4

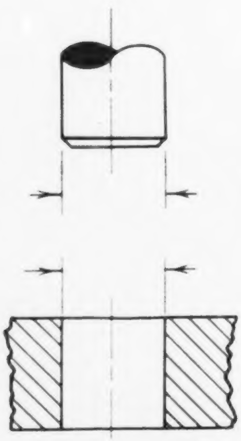
Assignment Sheet 3—Calculate and Dimension Interference Fit Tolerances using Standard Fit Tables

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Inch system dimensions completed	______
Metric system dimensions completed	______
Neatness and appearance	______

Directions: Calculate and dimension the following interference fit tolerances using standard fit tables.

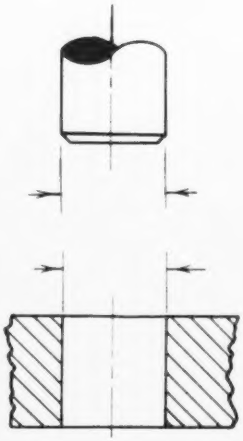
A. Inch system using ANSI B 4.1 - 1967, R 1987



Fit FN 4

Basic Size 3.00

Check fit



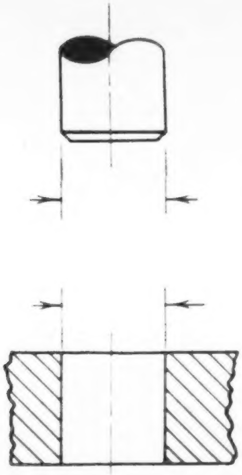
Fit LN 2

Basic Size .5

Check fit

Assignment Sheet 3

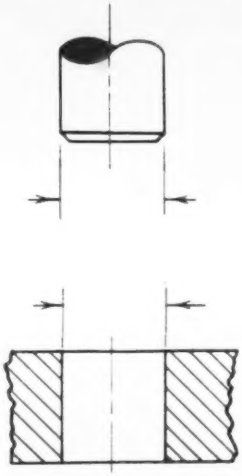
B. Metric system using ANSI B 4.2 - 1978, R 1983



Fit U7/h6

Basic Size 10

Check fit



Fit P7/h6

Basic Size 1.2

Check fit

Dimensioning and Tolerancing
Unit 4

Assignment Sheet 4—Calculate and Assign Tolerances to Mating Parts Using Standard Fit Table

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Metric system mating dimensions completed	_____
Inch system mating dimensions completed	_____
Neatness and appearance	_____

Directions: Calculate and assign tolerances to mating parts using standard fit tables for the metric and inch pulley assemblies shown on separate pages of this assignment sheet.

Metric System Tolerances

Specifications

SHAFT-BRACKET FIT (1) 12mm Nominal diameter Fit D9/h9	**SHAFT-BUSHING FIT (2)** 12mm Nominal diameter Fit F8/h9
BUSHING-PULLEY FIT (3) 20mm Nominal diameter Fit H7/p6	**PULLEYS-BRACKET FIT(4)** 50mm Nominal length Fit H11/c11

Show calculations below:

Shaft Bracket

Shaft Bushing

Bushing Pulley

Pulley Brackets

Assignment Sheet 4

Inch System Tolerances

Specifications

SHAFT-BRACKET FIT (1) .75 Nominal diameter Fit RC7	**SHAFT-BUSHING FIT (2)** .75 Nominal diameter Fit RC4
BUSHING-PULLEY FIT (3) 1.25 Nominal diameter Fit LN1	**PULLEYS-BRACKET FIT(4)** 3 Nominal length Fit RC8

Show calculations below:

Shaft Bracket

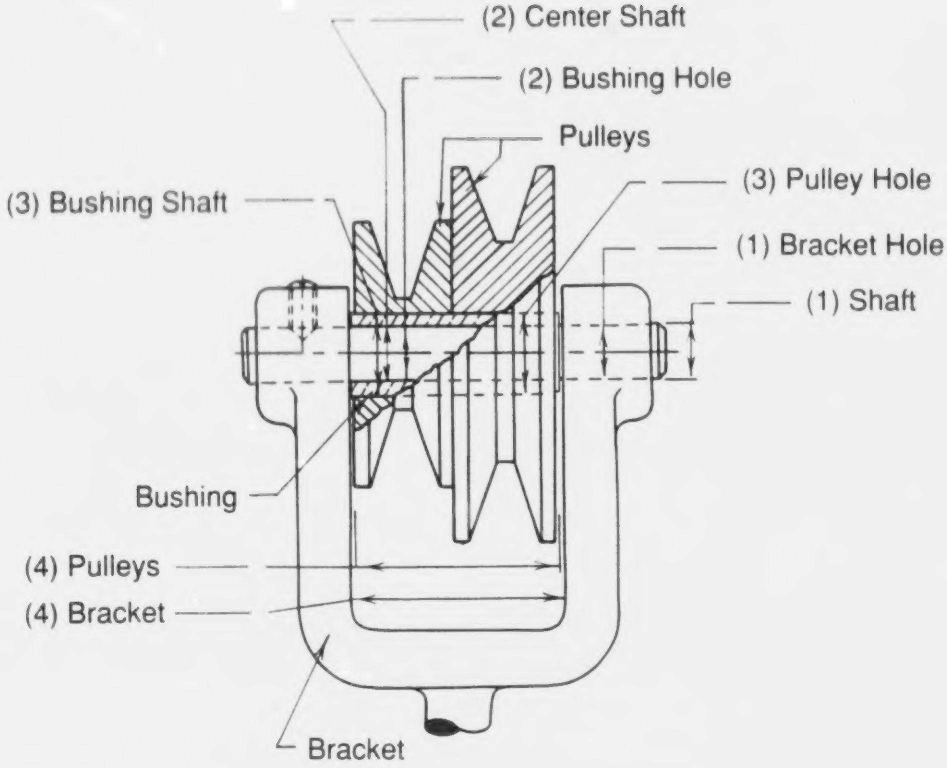
Shaft Bushing

Bushing Pulley

Pulley Brackets

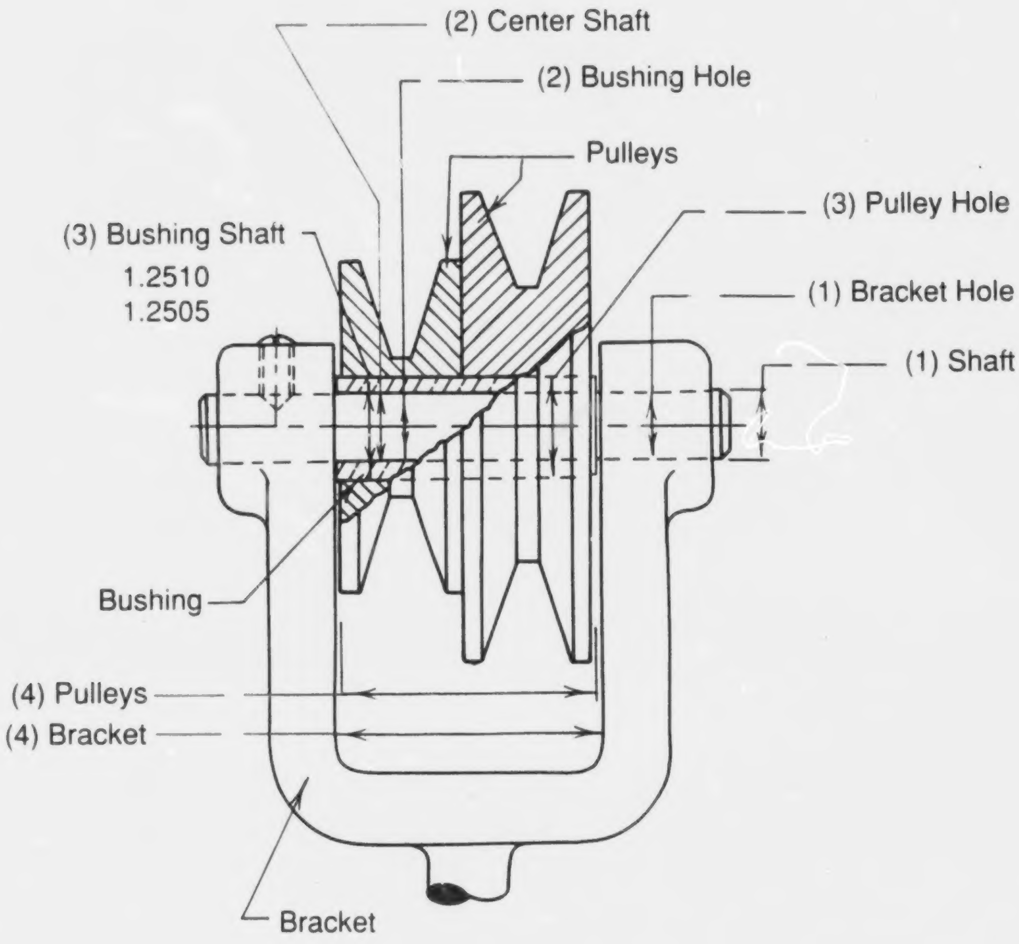
Assignment Sheet 4

Metric System Tolerancing


(2) Center Shaft
(2) Bushing Hole
Pulleys
(3) Bushing Shaft
(3) Pulley Hole
(1) Bracket Hole
(1) Shaft
Bushing
(4) Pulleys
(4) Bracket
Bracket

Assignment Sheet 4

Inch System Tolerancing


(2) Center Shaft
(2) Bushing Hole
Pulleys
(3) Pulley Hole
(3) Bushing Shaft
1.2510
1.2505
(1) Bracket Hole
(1) Shaft
Bushing
(4) Pulleys
(4) Bracket
Bracket

Dimensioning and Tolerancing
Unit 4

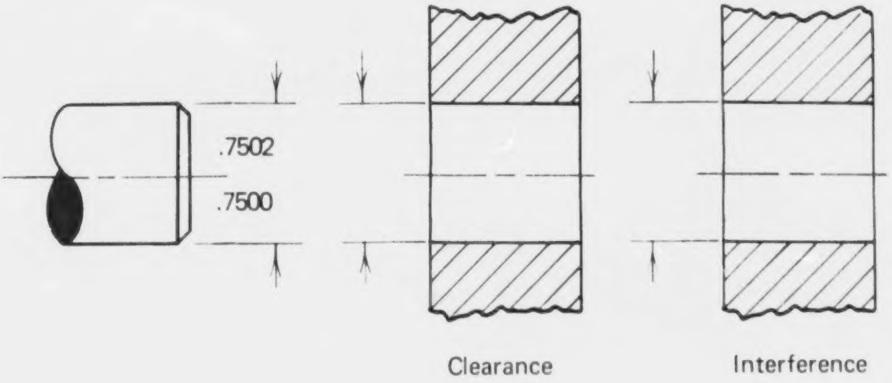
Assignment Sheet 5—Calculate and Dimension Hole-Size Limits For Standard Dowels

Name ______________________________ Overall Rating __________

Evaluation criteria	Rating
Sliding fit dimensions completed	______
Interference fit dimensions completed	______
Neatness and appearance	______

Directions: Calculate and dimension hole-size limits for standard dowels using basic shaft system. Use the appropriate tolerance tables for the problems.

Dowel limits = $\frac{.7502}{.7500}$



Problems:

A. For a sliding fit with limits of possible clearance from .003-.0012.

B. For an interference fit with limits of interference from .0006-.0019

Dimensioning and Tolerancing
Unit 4

Assignment Sheet 6—Dimension an Object Using Position and Form Tolerances

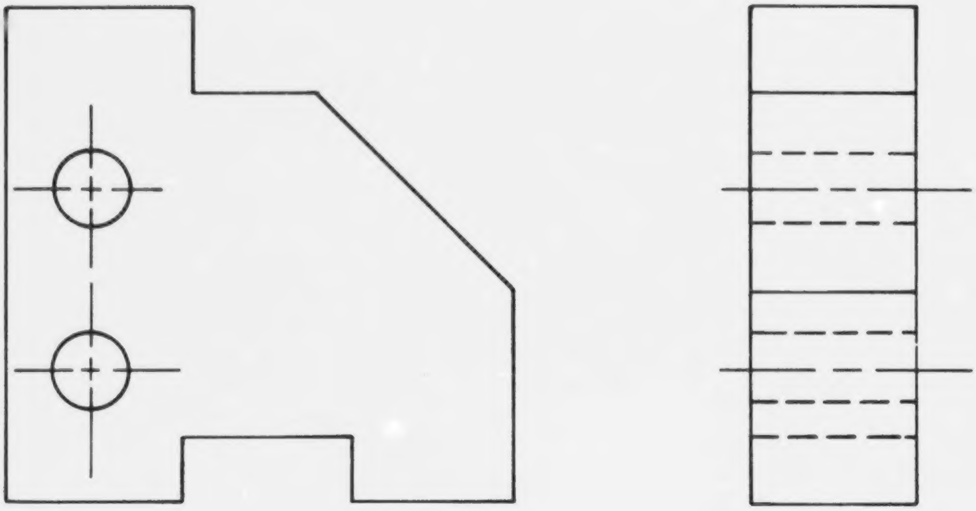
Name ______________________ Overall Rating __________

Evaluation criteria	**Rating**
Position tolerances completed	______
Forms tolerances completed	______
Neatness and appearance	______

Directions: Dimension an object using position and form tolerances to completely describe it; instructor or student may select datums as assigned.

> **CAD Alert:** Use a third-party dimensioning and tolerancing software program to complete this assignment. Learn how CAD can be applied to effectively save time.

Problem:



Dimensioning and Tolerancing
Unit 4

Assignment Sheet 7—Determine Ranges of Motion of Limbs and Spaces Required For a Person

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Number of problems attempted	______
Number of ranges of motion and space determined	______
Neatness and appearance	______

Directions: With the anthropometric data included at the end of this assignment sheet, solve the following problems by using the examples provided as guidelines.

Example 1: Find the width of the head of an adult in the 50 percentile group

a. Go to anthropometric data—Standing adult male

b. Go to 50 percentile drawing of man on chart

c. Locate head and read dimension above it

d. Answer 6.1″

Example 2: Find the reach radius of 50 percentile male

a. Go to anthropometric data—Adult male, seated at console

b. Go to view of man showing his reach radius

c. The reach radius is shown as:

30.7
28.5
26.5

d. The first number 30.7 is for the 97.5 percentile, the 28.5 is for the 50 percentile, and the 26.5 is for the 2.5 percentile

e. Answer 28.5″

Assignment Sheet 7

Problems:

A. Find the width of the shoulders of a 97.5 percentile adult male.

B. Find the height of a 50 percentile adult female.

C. Find the total visual limit in degrees from up to down.

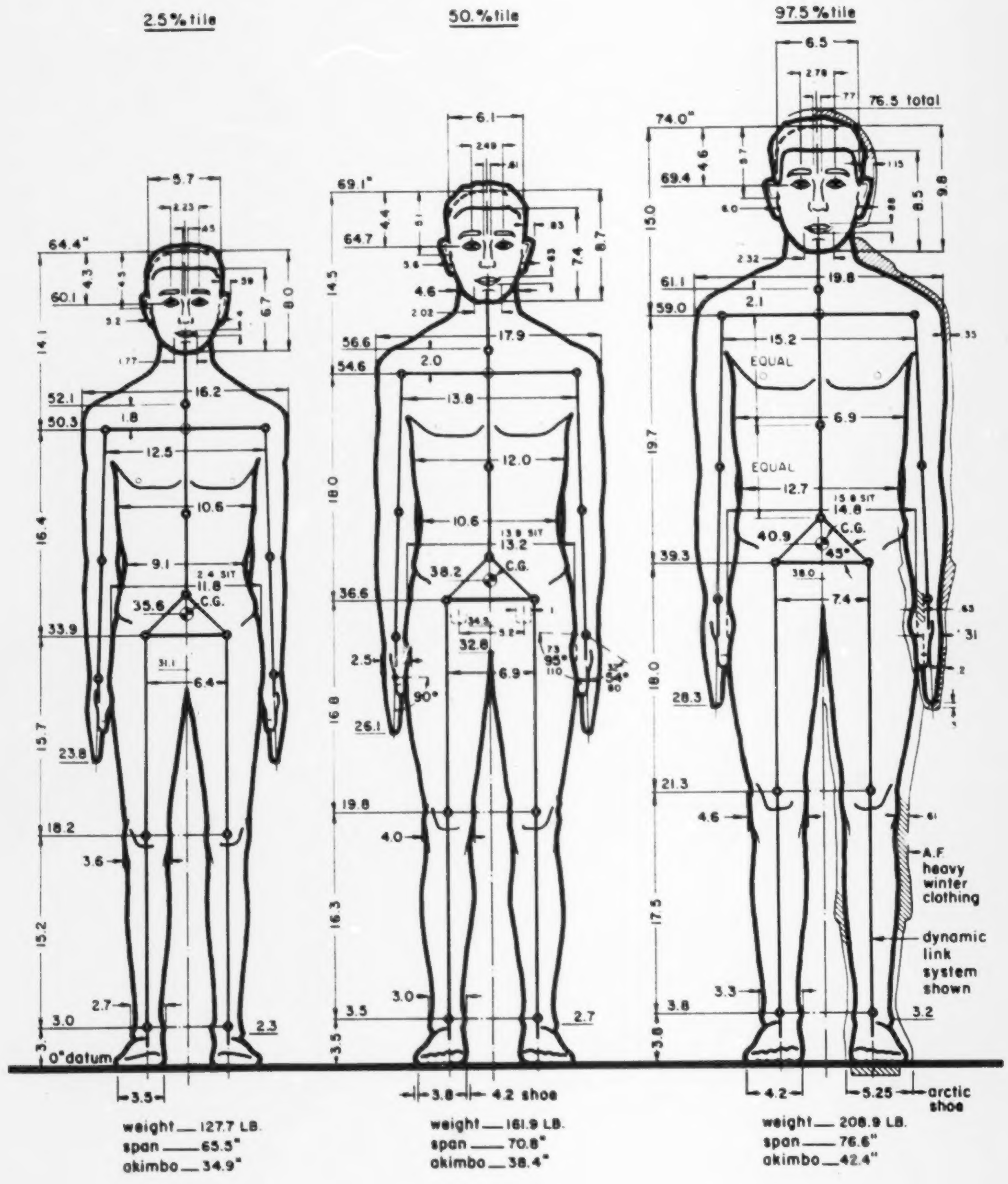
D. Find the maximum cylinder hand grasp for a 97.5 percentile adult male.

E. Find the average hand breadth of an 11 year-old child.

F. Find the average thumb length of a 50 percentile woman.

Assignment Sheet 7

ANTHROPOMETRIC DATA — STANDING ADULT MALE
Accomodating 95% of U.S. Adult Male Population


2.5%tile
50.%tile
97.5%tile
5.7
64.4"
60.1
52.1
50.3
16.2
1.8
12.5
10.6
9.1
2.4 SIT
11.8
35.6
C.G.
33.9
31.1
6.4
23.8
18.2
3.6
2.7
3.0
2.3
0"datum
3.5
14.1
16.4
15.7
15.2
6.1
69.1"
64.7
4.6
56.6
54.6
17.9
2.0
13.8
12.0
10.6
13.9 SIT
13.2
38.2
36.6
32.8
2.5
6.9
90°
95°
26.1
19.8
4.0
3.0
3.5
2.7
14.5
18.0
16.8
16.3
3.8
4.2 shoe
6.5
76.5 total
74.0"
69.4
61.1
59.0
19.8
2.1
15.2
EQUAL
6.9
EQUAL
12.7
15.8 SIT
14.8
40.9
C.G.
45°
39.3
38.0
7.4
28.3
21.3
4.6
3.3
3.8
3.2
15.0
19.7
18.0
17.5
4.2
5.25
arctic shoe
A.F heavy winter clothing
dynamic link system shown
weight — 127.7 LB.
span — 65.5"
akimbo — 34.9"
weight — 161.9 LB.
span — 70.8"
akimbo — 38.4"
weight — 208.9 LB.
span — 76.6"
akimbo — 42.4"

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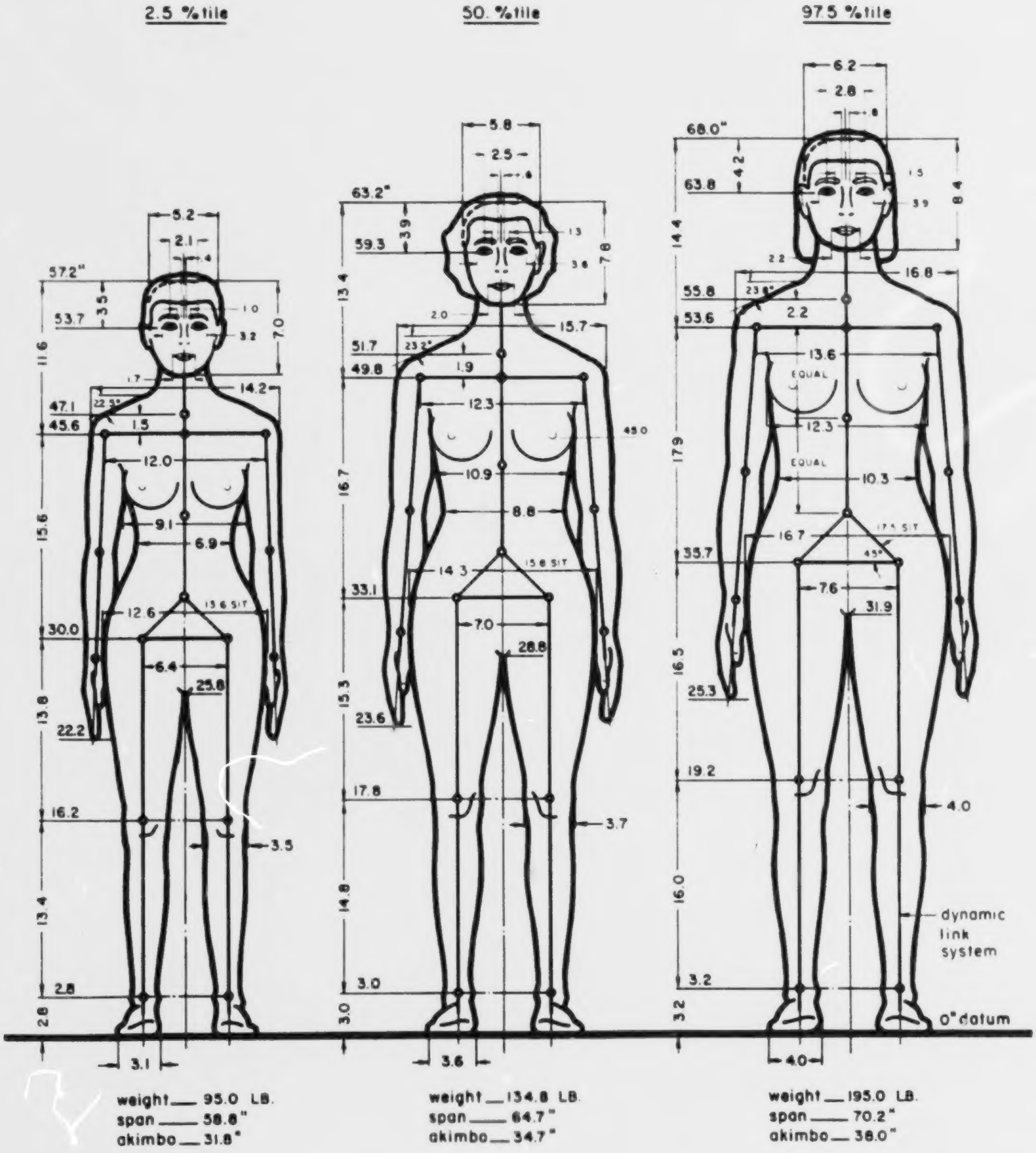
Assignment Sheet 7

ANTHROPOMETRIC DATA — STANDING ADULT FEMALE
Accomodating 95% of U.S. Adult Female Population


2.5 %tile
50. %tile
97.5 %tile
5.2
2.1
.4
57.2"
53.7
3.5
1.0
3.2
7.0
11.6
1.7
22.5°
14.2
47.1
45.6
1.5
12.0
15.6
9.1
6.9
12.6
13.6 SIT
30.0
6.4
25.8
13.8
22.2
16.2
3.5
13.4
2.8
3.1
weight — 95.0 LB.
span — 58.8"
akimbo — 31.8"
5.8
2.5
.6
63.2"
59.3
3.9
1.3
3.6
7.8
13.4
2.0
15.7
51.7
23.2°
49.8
1.9
12.3
45.0
16.7
10.9
8.8
14.3
15.6 SIT
33.1
7.0
28.8
15.3
23.6
17.8
3.7
14.8
3.0
3.6
weight — 134.8 LB.
span — 64.7"
akimbo — 34.7"
6.2
2.8
.8
68.0"
4.2
63.8
1.5
3.9
8.4
14.4
2.2
16.8
55.8
23.8°
53.6
2.2
13.6
EQUAL
17.9
12.3
EQUAL
10.3
16.7
17.5 SIT
45°
35.7
7.6
31.9
16.5
25.3
19.2
4.0
16.0
dynamic link system
3.2
0" datum
4.0
weight — 195.0 LB.
span — 70.2"
akimbo — 38.0"

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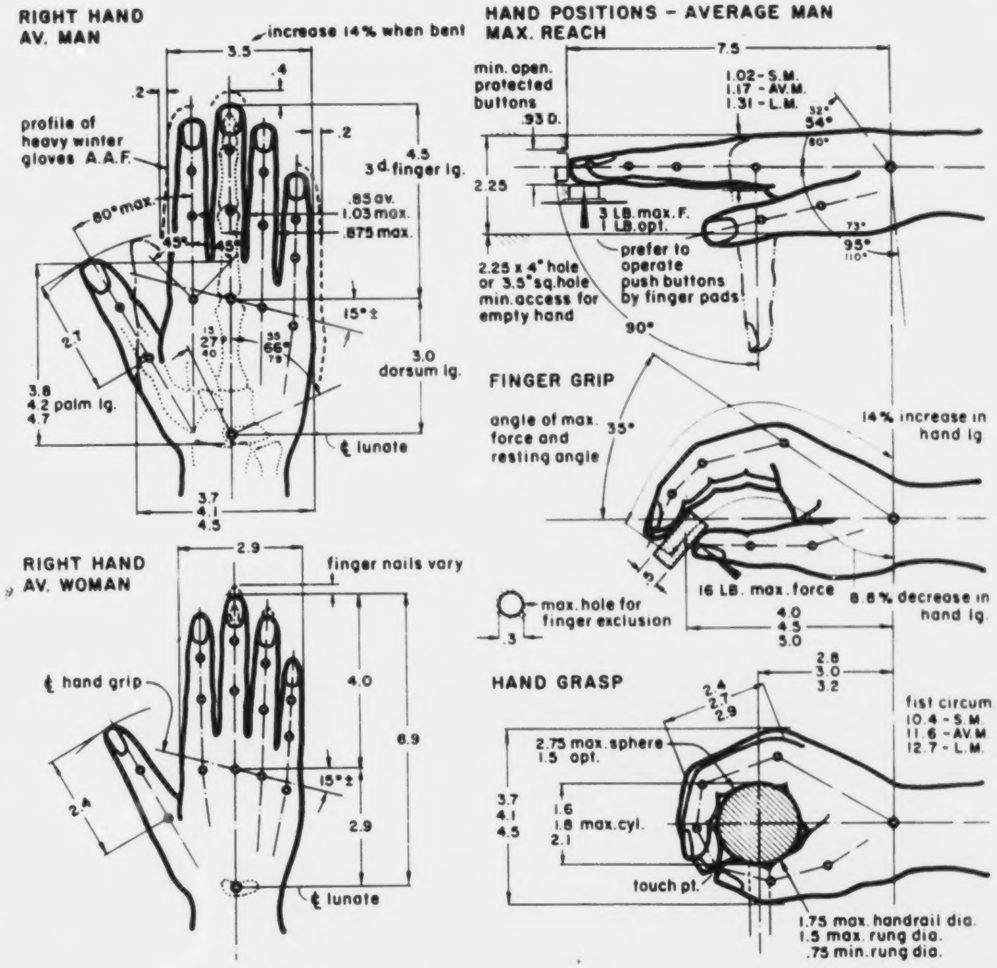
Assignment Sheet 7

HAND MEASUREMENTS OF MEN, WOMEN, AND CHILDREN


RIGHT HAND
AV. MAN
increase 14% when bent
3.5
.4
.2
profile of heavy winter gloves A.A.F.
4.5
3d finger lg.
.85 av.
1.03 max.
.875 max.
80° max.
45°
45°
15°±
2.7
3.0
dorsum lg.
3.8
4.2 palm lg.
4.7
℄ lunate
3.7
4.1
4.5
RIGHT HAND
AV. WOMAN
2.9
finger nails vary
℄ hand grip
4.0
6.9
15°±
2.4
2.9
℄ lunate
HAND POSITIONS - AVERAGE MAN
MAX. REACH
7.5
min. open. protected buttons
.93 D.
1.02 - S.M.
1.17 - AV.M.
1.31 - L.M.
32°
54°
80°
2.25
3 LB. max. F.
1 LB. opt.
73°
95°
110°
prefer to operate push buttons by finger pads
2.25 x 4" hole or 3.5" sq. hole min. access for empty hand
90°
FINGER GRIP
angle of max. force and resting angle
35°
14% increase in hand lg
16 LB. max. force
8.8% decrease in hand lg.
max. hole for finger exclusion
.3
4.0
4.5
5.0
HAND GRASP
2.8
3.0
3.2
2.4
2.7
2.9
fist circum.
10.4 - S.M.
11.6 - AV.M.
12.7 - L.M.
2.75 max. sphere
1.5 opt.
3.7
4.1
4.5
1.6
1.8 max. cyl.
2.1
touch pt.
1.75 max. handrail dia.
1.5 max. rung dia.
.75 min. rung dia.

HAND DATA	MEN			WOMEN			CHILDREN			
	2.5% tile	50.% tile	97.5% tile	2.5% tile	50.% tile	97.5% tile	6 yr.	8 yr.	11 yr.	14 yr.
hand length	6.8	7.5	8.2	6.2	6.9	7.5	5.1	5.6	6.3	7.0
hand breadth	3.2	3.5	3.8	2.6	2.9	3.1	2.3	2.5	2.8	—
3d finger lg.	4.0	4.5	5.0	3.6	4.0	4.4	2.9	3.2	3.5	4.0
dorsum lg.	2.8	3.0	3.2	2.6	2.9	3.1	2.2	2.4	2.8	3.0
thumb length	2.4	2.7	3.0	2.2	2.4	2.6	1.8	2.0	2.2	2.4

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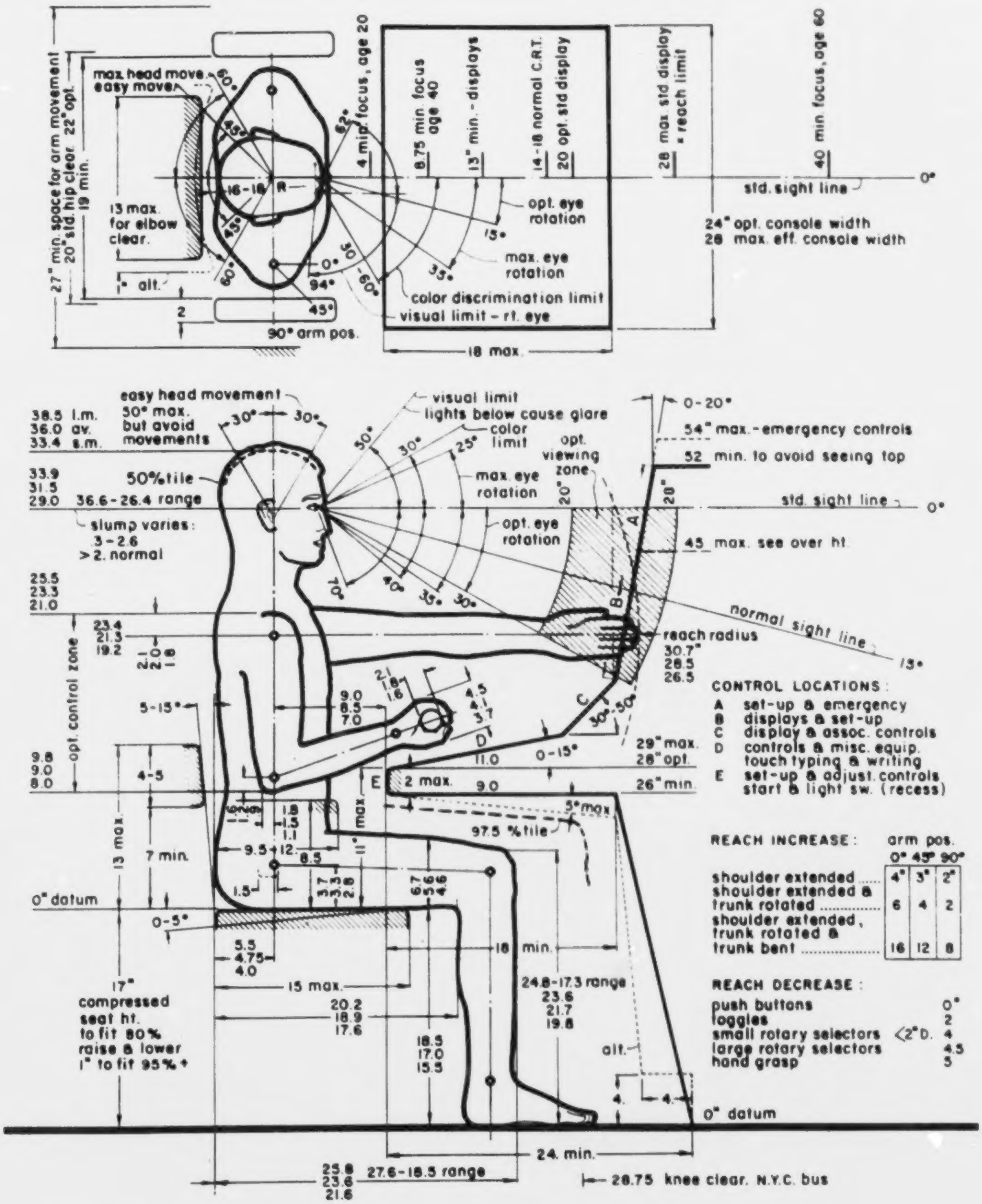
Assignment Sheet 7

ANTHROPOMETRIC DATA — ADULT MALE SEATED AT CONSOLE


27" min. space for arm movement
20" std. hip clear. 22" opt.
19 min.
max. head move. 60°
easy move.
45°
13 max. for elbow clear.
16-18
R
45°
60°
alt.
1"
2
0°
94°
45°
90° arm pos.
62°
4 min. focus, age 20
8.75 min. focus age 40
13" min. - displays
14-18 normal C.R.T.
20 opt. std display
28 max std display + reach limit
40 min focus, age 60
std. sight line
0°
opt. eye rotation
15°
max. eye rotation
35°
30-60°
color discrimination limit
visual limit - rt. eye
18 max.
24" opt. console width
28 max. eff. console width
easy head movement
38.5 l.m.
36.0 av.
33.4 s.m.
30° max. but avoid movements
30°
30°
visual limit
lights below cause glare
color limit
50°
30°
25°
opt. viewing zone
max. eye rotation
20°
20°
0-20°
54" max. - emergency controls
52 min. to avoid seeing top
std. sight line
0°
33.9
31.5
29.0
50%tile
36.6-26.4 range
slump varies: .3-2.6 >2. normal
opt. eye rotation
A
45 max. see over ht.
70°
40°
35°
30°
B
normal sight line
15°
25.5
23.3
21.0
23.4
21.3
19.2
1.0
2.2
2.8
reach radius
30.7"
28.5
26.5
opt. control zone
5-15°
9.0
8.5
7.0
2.1
1.8
1.6
4.5
4.1
3.7
C
30°-50°
D
11.0
0-15°
29" max.
28" opt.
26" min.
9.8
9.0
8.0
4-5
E
2 max.
9.0
CONTROL LOCATIONS:
A set-up & emergency
B displays & set-up
C display & assoc. controls
D controls & misc. equip. touch typing & writing
E set-up & adjust. controls start & light sw. (recess)
13 max.
7 min.
1.8
1.5
1.1
11" max
5° max
97.5 %tile
9.5
12.
8.5
1.5
0" datum
0-5°
7.3
6.3
5.2
6.7
6.5
6.4
18 min.
5.5
4.75
4.0
15 max.
17" compressed seat ht. to fit 80% raise & lower 1" to fit 95%+
20.2
18.9
17.6
18.5
17.0
15.5
24.8-17.3 range
23.6
21.7
19.8
alt.
4.
4.
0" datum
24. min.
25.8
23.6
21.6
27.6-18.5 range
28.75 knee clear. N.Y.C. bus
REACH INCREASE: arm pos. 0° 45° 90°
shoulder extended 4" 3" 2"
shoulder extended & trunk rotated 6 4 2
shoulder extended, trunk rotated & trunk bent 16 12 8
REACH DECREASE:
push buttons 0"
toggles 2
small rotary selectors <2"D. 4
large rotary selectors 4.5
hand grasp 5

6.6-9.% left handed, 3.5-6.% color blind, 4.5% hard of hearing, 29.3% wear glasses

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Fasteners and Hardware
Unit 5

Objective Sheet

Unit Objective

After completing this unit, the student should be able to draw symbols for fasteners and hardware to include constructing spring and key drawings, and reference vendor's catalogs to write hardware specifications. The student should demonstrate these competencies by completing the assignment and job sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to fasteners and hardware with their correct definitions.
2. Match thread nomenclatures with their meanings.
3. Match other fasteners with their applications.
4. Complete statements about screw heads and their uses.
5. Apply screw thread nomenclature to a drawing.
6. Identify screw thread profiles.
7. Compute given thread leads.
8. Identify ways of presenting screw threads.
9. Match classes of fit for unified and metric threads with their applications.
10. Identify parts of thread notes for American National screw threads.
11. Identify parts of thread notes for American National Standard Unififed screw threads.

Objective Sheet

12. Identify parts of thread notes for metric screw threads.
13. Differentiate between ways to present pipe threads.
14. Identify types of threaded removable fasteners.
15. Select true statements about types of locknuts and locking devices.
16. Distinguish between types of standard cap screws.
17. List types of machine screws.
18. Identify types of heads and points on set screws.
19. Identify miscellaneous bolts, nuts, and screws.
20. Identify standard large and small rivets.
21. Differentiate between conventional rivet symbols and their meanings.
22. Complete statements about advantages of plastic fasteners over metal fasteners.
23. Identify shaft locking hardware.
24. Match types of springs with their characteristics.
25. Identify types of springs from their notes and dimensions.
26. Match types of spring clips with their designs.
27. List types of keys designed to prevent relative motion between wheel and shaft.
28. Identify types of machine pins.
29. Match types of washers with their applications.
30. Identify types of tooth lock washers.
31. Match insert characteristics with their industrial applications.
32. Complete statements about industrial applications of spring washer designs.
33. Identify quick opening and quick locking devices.
34. Match miscellaneous machine elements with their uses.

Objective Sheet

35. Select true statements about advantages of welding instead of using threaded fasteners.

36. Identify basic types of welded joints.

37. Label parts of a welding symbol.

38. Identify basic arc and gas welding symbols.

39. Solve problems concerning supplementary welding sysmbols.

40. use guidelines for dimensioning welds to determine the dimensions of a fillet weld.

41. Identify resistance welding symbols.

42. Complete statements about considerations for using adhesives for bonding materials.

43. Solve a problem about considerations for joint design when using adhesive bonding.

44. Identify joint designs for adhesive bonding.

45. Complete statements about CAD symbol libraries and their uses.

46. Construct thread symbols. (Assignment Sheet 1)

47. Construct symbols of bolts, screws, and nuts. (Assignment Sheet 2)

48. Construct an assembly containing various fasteners. (Assignment Sheet 3)

49. Construct a weldment assembly drawing. (Assignment Sheet 4)

50. Construct spring drawings to include specifications. (Assignment Sheet 5)

51. Construct keys in assembled positions. (Assignment Sheet 6)

52. Write specifications for hardware from vendor catalogs. (Assignment Sheet 7)

Fasteners and Hardware
Unit 5

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for enrichment of exceptional students as well as accommodation of special needs students.
4. Make transparencies from the transparency masters included with this unit. These appear in the teacher edition only and are designed to be used with the following objectives:

   TM 1—American National Thread Notes for Holes (Objective 10)
   TM 2—American National Thread Notes for Threaded Shaft (Objective 10)
   TM 3—American Standard Unified Thread Notes (Objective 11)
   TM 4—Metric Thread Notes (Objective 12)
   TM 5—Pipe Threads (Objective 13)

5. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.
6. Develop teaching plan. Adjust for different learning styles.
7. Make copies of Unit Evaluation Form.

Delivery and Application

8. Provide students with unit of instruction.
9. Discuss unit and specific objectives.
10. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
11. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Suggested Activities

Evaluation

12. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

13. Make copies of the written test. Add or modify test items as needed.

14. Give written test.

15. Compile assignment sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignments.

16. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Review the unit carefully. It is a long unit and will require extra time to teach. Break the unit into parts that will be easy for students to work with. Plan to administer the test in two or even three parts.

2. Prepare as many examples of fasteners and hardware as you have time to. Have hardware vendor catalogs handy so students can look over hardware and fasteners not shown in this unit. Skill areas: **Foundation skills, reading**.

3. Help students prepare for Assignment Sheet 7. Use the same vendor catalog or catalogs mentioned in item 2. If you are short of catalogs, have two or more students work together to complete the assignment, and add extra items to the assignment sheet. Skill areas: **Group effectiveness skills, teamwork**.

Resources Used in Developing This Unit

1. *Basics of Machine Design Reference Volume.* Cleveland, OH: Penton Publishing, 1993.

2. *Fastener Standards*, 6th Ed. Cleveland, OH: Industrial Fasteners Institute, 1988.

3. *Fundamentals of Service, Fasteners.* Moline, IL: Deere & Company, 1992.

Suggested Activities

4. Jensen, Cecil, et. al. *Computer-Aided Engineering Drawning Using AutoCAD*. New York: Glencoe/McGraw Hill Education Division, 1990.

5. Shigley, Joseph E., and Charles R. Mischke. *Fastening, Joining, and Connecting: A Mechanical Designers' Handbook*. New York: McGraw-Hill, 1990.

Suggested Supplemental Resources

1. *Fasteners Standards*, 6th Edition is available directly from the publisher for $89.50 (no educational discount). For information, write:

   Industrial Fasteners Institute
   1717 E. 9th Street, Suite 1005
   Cleveland, OH 44114

   or phone 216-241-1482

2. *Basics of Machine Design Reference Volume* is published as a master reference from the magazine, *Machine Design*. This publication replaces the "Fastening and Joining Reference Issue", and includes a much braoder scope of reference material along with expanded references especially for CAD/CAM. The book is available to the public for $70.00, but there is an educational discount: $50 for 1 to 24 books; $45 for 25 to 49; $40 for 50 to 99; $35 for more than 100. For information, write:

   Penton Education Division
   1100 Superior Avenue
   Cleveland, OH 44114

   or phone: 1-800-321-7003

3. *Fundamentals of Service, Fasteners* is available for $9.95 from the publisher. Orders of 10 or more receive a 10% discount. For information, write:

   Distribution Service Center
   Deere & Company
   1400 13th Street
   East Moline, IL 61244

   or phone: 1-800-522-7448

Fasteners and Hardware
Unit 5

Answers to Assignment Sheets

Assignment Sheets 1 through 7

Evaluate all assignment sheets according to criteria written in the assignment sheet.

Fasteners and Hardware
Unit 5

Answers to Written Test

1. a. 4
   b. 6
   c. 2
   d. 1
   e. 3
   f. 5
   g. 7

2. a. 5
   b. 6
   c. 1
   d. 8
   e. 9
   f. 2
   g. 3
   h. 7
   i. 4

3. a. 4
   b. 6
   c. 5
   d. 9
   e. 8
   f. 3
   g. 1
   h. 2
   i. 7

4. a. Flat blade
   b. Clutch

5. a. Depth
   b. Crest
   c. Root
   d. Side
   e. Minor diameter
   f. Pitch diameter
   g. Major diameter
   h. Pitch
   i. Thread angle

6. a. Sharp V
   b. American National
   c. Unified
   d. Square
   e. Acme
   f. Whitworth Standard
   g. Metric
   h. Knuckle
   i. Buttress

Answers to Written Test

7. a. L = 1/10
   b. L = 2/18 or 1/9
   c. L = 3/24 or 1/8

8. a. Simplified
   b. Schmatic
   c. Detailed

9. a. 5
   b. 2
   c. 3
   d. 1
   e. 4

10. a. Major dia
    b. Threads per inch
    c. National course
    d. Class of fit
    e. Left hand
    f. Depth of thread

11. a. Major dia
    b. Threads per inch
    c. Unified form fine series
    d. Class of fit
    e. External thread

12. a. Metric thread form
    b. Major dia
    c. Pitch
    d. Class of fit
    e. Internal
    f. Left hand

13. b

14. a. Bolt
    b. Stud
    c. Cap screw
    d. Machine screw
    e. Set screw

15. a, c, d

Answers to Written Test

16. a. H
    c. R
    e. F

17. (Items may be in any order)
    a. Round head
    b. Flat head
    c. Oval head
    d. Fillister head

18. a. 4   f. 10
    b. 2   g. 5
    c. 3   h. 6
    d. 8   i. 7
    e. 9   j. 1

19. a. Eye bolt
    b. Step bolt
    c. Square neck bolt
    d. Clevis bolt
    e. Wing nut
    f. Tapping screw

20. a. Button head
    b. Cone head
    c. Countersunk head
    d. Button head

21. a

22. a. Lighter, are
    b. Insulators

23. a. Round end key
    b. Woodruff key
    c. Square key
    d. Flat key
    e. Taper pin
    f. Gib head key
    g. Taper pin
    h. Cotter pin
    i. Retaining ring, internal
    j. Retaining ring, external
    k. Self locking, external

Answers to Written Test

24. a. 3
    b. 4
    c. 1
    d. 2

25. a. Extension spring
    b. Compression spring

26. a. 3
    b. 5
    c. 1
    d. 2
    e. 4

27. Any four of the following:

    a. Square
    b. Round
    c. Flat
    d. Gib head
    e. Pratt and Whitney
    f. Woodruff

28. a. 2
    b. 4
    c. 1
    d. 3

29. a. 2
    b. 4
    c. 5
    d. 1
    e. 3

30. a. 4
    b. 5
    c. 1
    d. 3
    e. 2

31. a. 3
    b. 4
    c. 1
    d. 2

Answers to Written Test

32. a. Adjacent
    b. Take-up
    c. End pressure
    d. End play

33. a. 3
    b. 4
    c. 2
    d. 1

34. a. 5
    b. 3
    c. 1
    d. 8
    e. 7
    f. 6
    g. 2
    h. 4

35. a, b, c

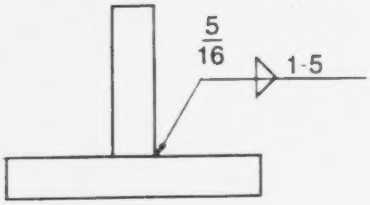
36. a. 5
    b. 3
    c. 2
    d. 1
    e. 4

37. a. 2
    b. 4
    c. 5
    d. 3
    e. 7
    f. 6
    g. 1

38. a. 3
    b. 5
    c. 2
    d. 6
    e. 1
    f. 4

39. a. (3)
    b. (2)

40.



41. a. Resistance seam weld
    b. Flash or upset weld

Answers to Written Test

42. a. Structural
    b. Chemical
    c. Hot melt
    d. Glass

43. (2)

44. a. 4
    b. 3
    c. 2
    d. 1

45. A. Top
    b. Weld
    c. Holes

Fasteners and Hardware
Unit 5

Written Test

Name ______________________________ Date ________________ Score ____________

1. Match the terms on the right with their correct definitions.

_____a. A mechanical device for holding two or more parts in a set position

_____b. A fastener made to close tolerance with a high grade finish

_____c. A fastener having high tensile and shear strength

_____d. A fastener made with greater tolerances than a finished fastener with only the bearing surface and threads finished

_____e. A fastener such as a rivet, adhesive, or weld that is not designed to be removed

_____f. A fastener such as a bolt, key, or screw which can be removed

_____g. Standard representation of fasteners, springs, welds, and features in a CAD library

1. Semi-finished fasteners
2. High strength fastener
3. Permanent fastener
4. Fastener
5. Removable fastener
6. Finished fastener
7. Symbol libraries

2. Match thread nomenclatures with their meanings. Place the number of the nomenclature in the blank beside the correct meaning.

_____a. Thread on the outside of a shaft

_____b. Thread on the inside of a hole

_____c. The distance a screw travels in one rotation

_____d. A thread that advances when turned couterclockwise

1. Lead
2. Right-hand thread
3. Series of thread
4. Feature
5. External thread

Written Test

______e. A thread having more than one start with the lead equal to a multiple of the pitch

______f. A thread that advances when turned clockwise

______g. The number of threads per inch based on standard nominal diameters

______h. A thread having one start with the lead equal to the pitch

______i. A hole, slot, or special shape in 2D or 3D produced by hand drawing or CAD

6. Internal thread
7. Single thread
8. Left-hand thread
9. Multiple threads

3. Match other fasteners with their applications. Place the number of the fastener in the blank beside its description.

______a. Chemical bonding between parts

______b. Small parts such as fasteners, springs, and washers

______c. Devices used to attach wheels, pulleys, and gears to shafts

______d. Devices for fastening, adjusting, and transmitting motion or power

______e. Devices used to seal along a shaft

______f. Devices used for semi-permanent attachment or location

______g. Devices with removable shoulders so they can accurately retain, locate, or lock components in bases, housings, or on shafts

______h. Devices that insulate, lubricate, span large holes, or distribute stress over a larger area

______i. The joining of parts by melting base metal to form a unit structure to support a load

1. Retaining rings
2. Washers
3. Pins
4. Adhesive
5. Keys
6. Hardware
7. Welding
8. O-Rings
9. Nuts

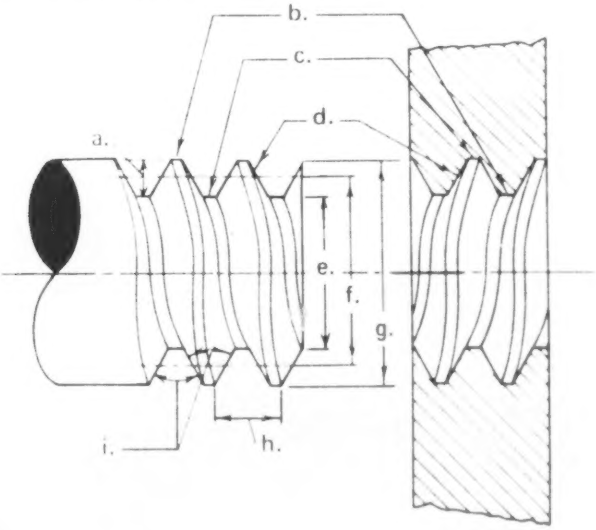
Written Test

4. Complete statements about types of screw heads and their uses. Circle the material that best completes each of the following statements.

   a. Slotted heads are used with (**broad blade**) (**flat blade**) screwdrivers and are used just about everywhere, around the house and in industry where service requirements do not require extra strength.

   b. Recessed heads have a centered indentation that permits them to be used with a special type of scredriver; the most common are the cross or Phillips head, the socket head, and the (**clutch**) (**cross-hatch**) head.

5. Apply screw thread nomenclature to the following drawing. Write the correct nomenclature in the appropriate blank.

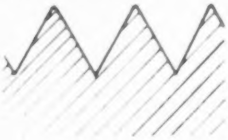
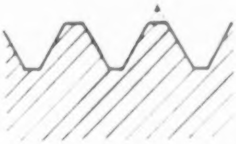
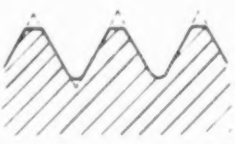


a. ____________ b. ____________ c. ____________

d. ____________ e. ____________ f. ____________

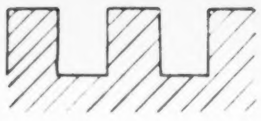
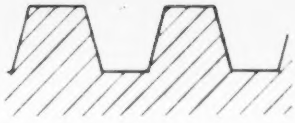
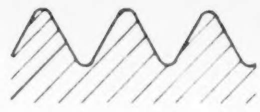
g. ____________ h. ____________ i. ____________

6. Identify screw thread profiles. Write the name of the profile below each of the following illustrations.

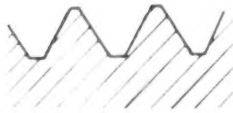
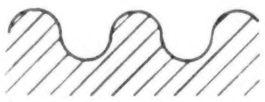
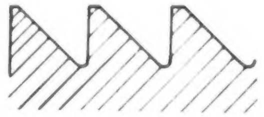




a. ____________ b. ____________ c. ____________

Written Test

d. ____________ e. ____________ f. ____________

g. ____________ h. ____________ i. ____________

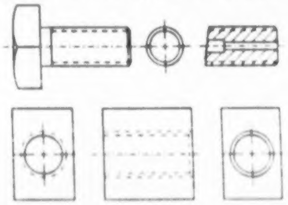
7. Compute given thread leads. Use the given thread conditions to find the L (lead) for each of the following conditions.

   a. Single thread, 10 threads per inch L = ____________

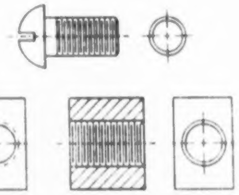
   b. Double thread, 18 threads per inch L = ____________

   c. Triple thread, 24 threads per inch L = ____________

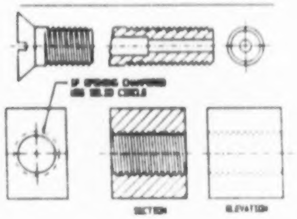
8. Identify ways of presenting screw threads. indicate beneath each of the following illustrations the type of presentation it makes.



a. ____________________



b. ____________________



c. ____________________

Written Test

9. Match classes of fit for unified and metric threads with their applications. Place the number beside the class beside the description of its application.

______ a. used for parts that are easy to assemble or quick to assemble; also used for ordinance and other special uses

______ b. Used for general purpose applications; most common uses

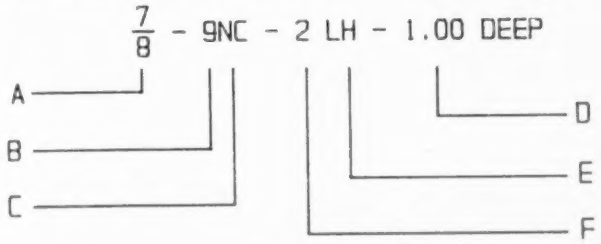
______ c. Used for applications specifying close tolerances

______ d. Used for UNC or NC; these are preferred by most commercial users

______ e. Used for UNF or NF

1. Coarse or general purpose metric threads
2. Class 2A and 2B unified threads
3. Class 3A and 3B unified threads
4. Fine metric threads
5. Class 1A and 1B unified threads

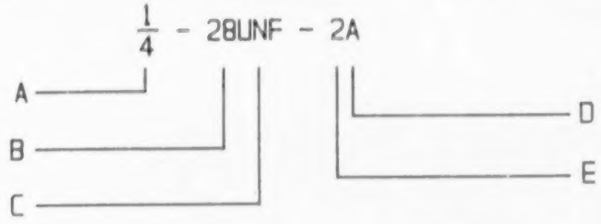
10. Identify parts of thread notes for American National screw threads.



a. ______ b. ______ c. ______ d. ______

e. ______ f. ______

11. Identify parts of thread notes for American National Standard Unified screw threads.

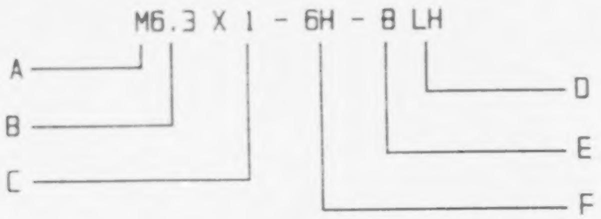


a. ______ b. ______ c. ______

d. ______ e. ______

Written Test

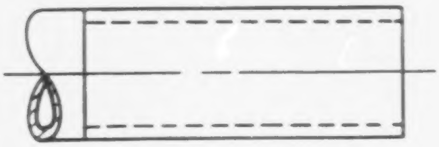
12. Identify parts of thread notes for metric screw threads.



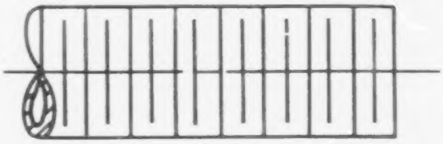
a. ______________ b. ______________ c. ______________

d. ______________ e. ______________ f. ______________

13. Differentiate between ways to present pipe threads. Place an "X" beneath the illustration that shows a schematic presentation.

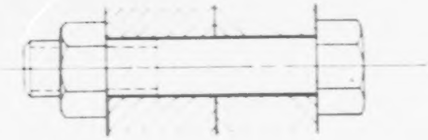


a. ______________

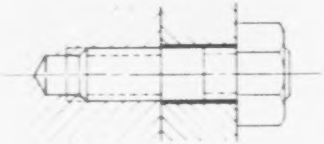


b. ______________

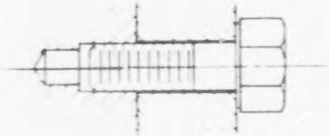
14. Identify types of threaded removable fasteners. Place the name of the removable fastener in the blank below its illustration.



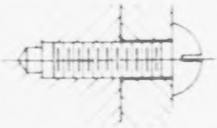
a. ______________



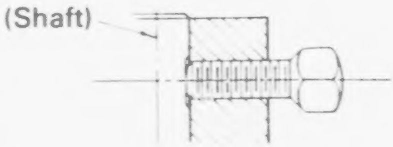
b. ______________



c. ______________



d. ______________



e. - ______________

Written Test

15. Select true statements about types of locknuts and locking devices. Place an "X" beside each grouping that indicates locknuts or locking devices.

_______a. Nuts that lock with cotter pins

_______b. Nuts that lock with threaded wire

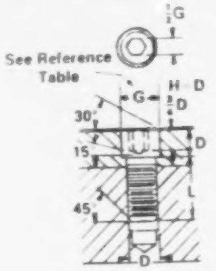
_______c. Jam nuts

_______d. Screw and washer assemblies

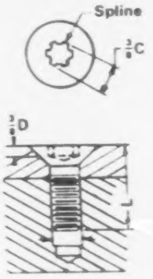
_______e. Shaft and jam nut assemblies

16. Distinguish between types of standard cap screws. Place an "R" beside a round head, and "F" beside a fillister head, and an "H" beside a hex socket head.

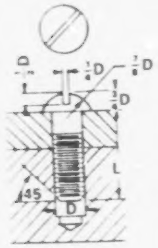
_______a.


See Reference Table
G
H D
30°
15°
45°
L
D

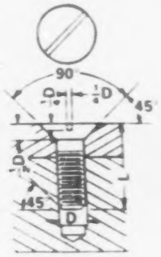
_______b.



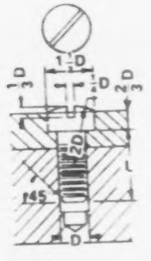
_______c.



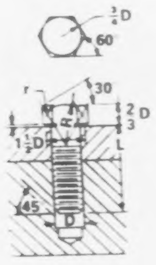
_______d.



_______e.



_______f.



Written Test

17. List the four types of machine screws.

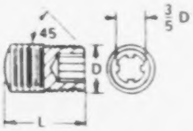
a. ____________________

b. ____________________

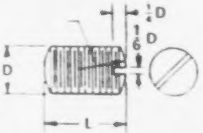
c. ____________________

d. ____________________

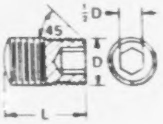
18. Identify types of heads and points on set screws. Place the number of the head or point type in the blank under its illustration.



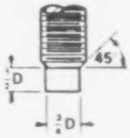
a. ______________



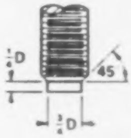
b. ______________



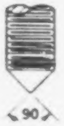
c. ______________



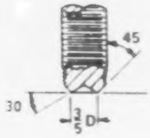
d. ______________



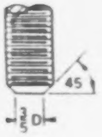
e. ______________



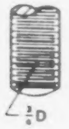
f. ______________



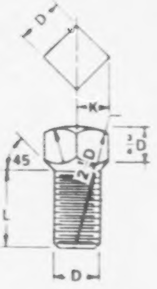
g. ______________



h. ______________



i. ______________

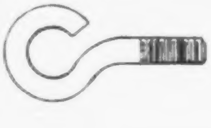


j. ______________

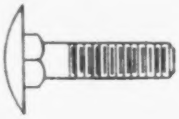
1. Square head
2. Slotted
3. Hex socket
4. Socket spline
5. Cup point
6. Flat point
7. Oval point
8. Full dog point
9. Half dog point
10. Cone point

Written Test

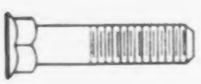
19. Identify miscellaneous bolts, nuts, and screws. Write the name of the fastener below its illustration.



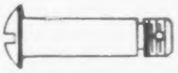
a. ______________________



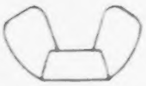
b. ______________________



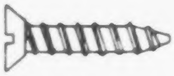
c. ______________________



d. ______________________

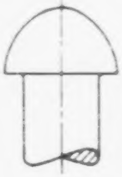


e. ______________________

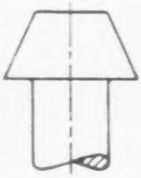


f. ______________________

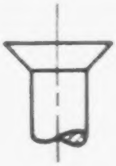
20. Identify standard large and small rivets. Place the name of the rivet type below its illustration.



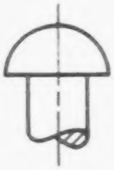
a. ______________________



b. ______________________



c. ______________________

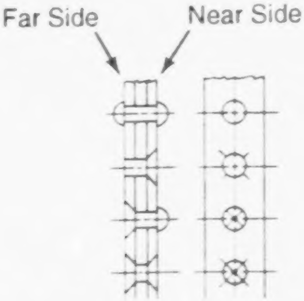


d. ______________________

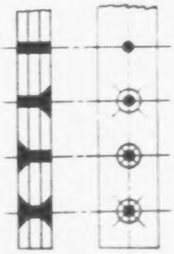
Written Test

21. Differentiate between shop rivets and field rivets. Place an "S" beside the illustration of shop rivets.

______ a.



______ b.

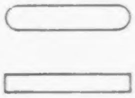
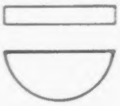


22. Complete statements about advantages of plastic fasteners over metal fasteners. Circle the material that best completes each of the following statements.

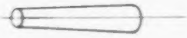
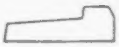
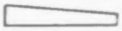
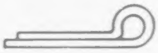
   a. Plastic fasteners are (**heavier**) (**lighter**) weight than metal fasteners, and plastic fasteners (**are**) (**are not**) corrosion resistant.

   b. Plastic fasteners make excellent thermal and electrical (**conductors**) (**insulators**) and they are easy to color code.

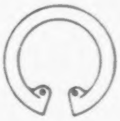
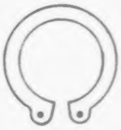
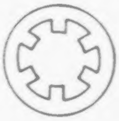
23. Identify shaft locking hardware. Write the name of the fastener below its illustration.

a. ______ b. ______ c. ______ d. ______

e. ______ f. ______ g. ______ h. ______

i. ______ j. ______ k. ______

Written Test

24. Match types of springs with their characteristics. Place the number of the spring type in the blank beside the definition of its characteristics.

_____a. Used to absorb or custion forces

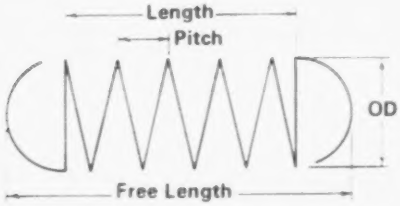
_____b.. Used in application where they stretch and pull back to an original position

_____c. Used in many different shapes that involve twisting

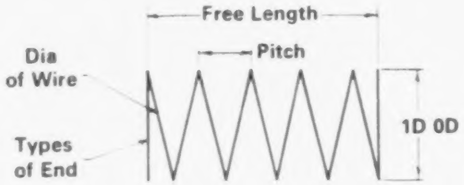
_____d. Used in a variety of shapes that absorb energy

1. Torision
2. Flat
3. Compression
4. Extension

25. Identify types of springs from their notes and dimensions. Write the name of the spring type below the illustration.


Length
Pitch
OD
Free Length

a. ____________________


Free Length
Pitch
Dia of Wire
Types of End
1D 0D

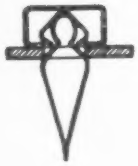
b. ____________________

Written Test

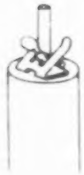
26. Match types of spring clips with their designs. Place the number of the clip type in the blank baside its illustration.

1. Cable, wiring, and tubing clips
2. Dart-type clips
3. Spring molding clip
4. U-shaped, S-shaped, and C-shaped clips
5. Stud receiver clip

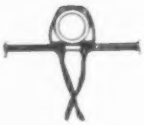
______ a.



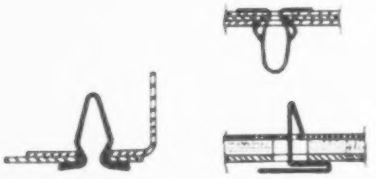
______ b.



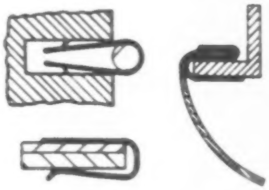
______ c.



______ d.



______ e.



27. List four types of keys designed to prevent relative motion between wheel and shaft.

a. ______________

b. ______ ______

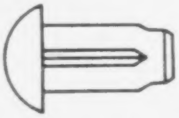
c. ______________

d. ______________

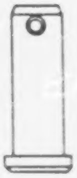
Written Test

28. Identify types of machine pins. Place the number of the pin in the blank beside its illustration.

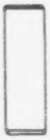
______a.



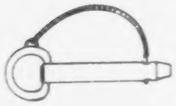
______b.



______c.



______d.



1. Dowel
2. Drive
3. Quick release
4. Clevis

29. Match types of washers with their applications. Place the number of the washer type in the blank beside its definition.

______a. Used on bearing surfaces for heavy or standard applications

______b. Used in conjunction with spring action

______c. Used for locking applications

______d. Used for built-in pressure applications

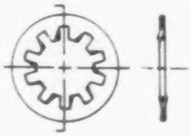
______e. Used in plated or unplated varities in decorations and other craft applications

1. Spring washers
2. Flat washers
3. Special purpose washers
4. Conical washers
5. Helical spring washers

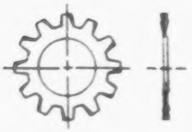
Written Test

30. Identify types of tooth lock washers. Place the number of the washer type in the blank beside its illustration.

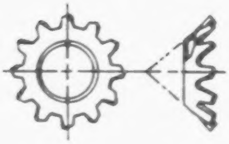
_____a.



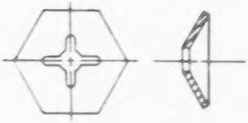
_____b.



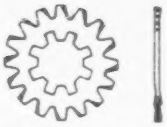
_____c.



_____d.



_____e.



1. Countersunk
2. External-internal
3. Pyramidal
4. Internal
5. External

31. Match insert characteristics with their industrial applications. Place the number of the industrial application in the blank beside the description of the characteristic.

_____a. Inserts add higher strength

_____b. Inserts are used to make permanent threads

_____c. Inserts are used for internal locking of threaded holes

_____d. Inserts permit mating screw assembly without damage to metal

1. Thin parts
2. Reassembly
3. Light alloys and plastics
4. Ferrous alloys

Written Test

32. Complete statements about industrial applications of spring washer designs. Circle the material that best completes each of the following statements.

    a. Spring washers are designed to provide pressure on (**mating**) (**adjacent**) parts.

    b. Spring washers can act as (**take-up**) (**balancing**) devices in an assembly.

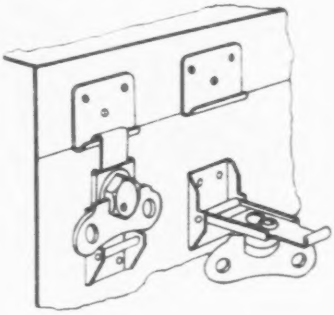
    c. Spring washers can control (**stress**) (**end pressure**).

    d. Spring washers are used to eliminate (**end pressure**) (**end play**).

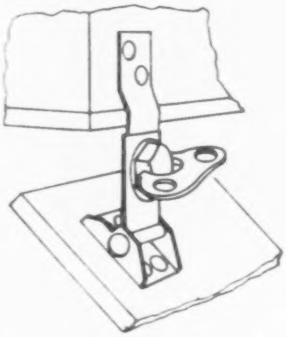
33. Identify quick opening and quick locking devices. Place the number of the device in the blank beside its illustration.

    1. Quarter turn
    2. Hook lock
    3. Link lock
    4. Hinge lock

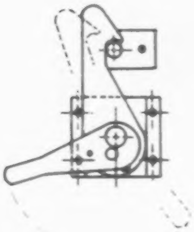
_______a.



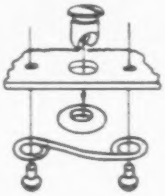
_______b.



_______c.



_______d.



Written Test

34. Match miscellaneous machine elements with their uses. Place the number of the machine element in the blank beside the description of its use.

______a. Permit rapid assembly and disassembly of parts

______b. A resistance weld process used to weld nuts to a surface

______c. A resistance weld process used to weld studs to a surface

______d. Help prevent leaks at joints

______e. Used to cut mating threads in metal or plastic

______f. Help prevent nuts from rotating

______g. Permit manual fastening with fingers

______h. Save time at assembly

1. Spt weld
2. Wing nuts
3. Projection weld
4. Screw and washer assemblies
5. Quick release pins
6. Captive nuts
7. Self-tapping screws
8. Stud weld fasteners

35. Select true statements about advantages of welding instead of using threaded fasteners. Place an "X" beside each true statement.

______a. Welding saves both time and expense because welding processes are fast and relatively simple.

______b. In most cases, welding produces less weight than a casting or forged part.

______c. Welding produces less noise and leaves a neater appearance.

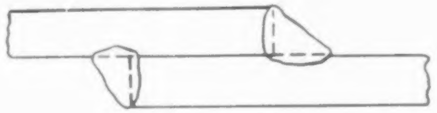
______d. Welding makes painting difficult, but looks better.

______e. All in all, welding is a good process for large quantity jobs.

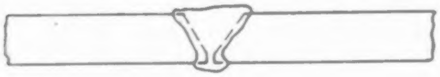
Written Test

36. Identify basic types of welded joints. Place the number of the joint type in the blank beside its illustration.

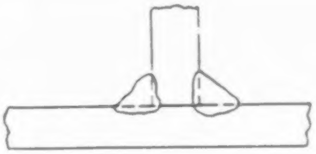
_____ a.



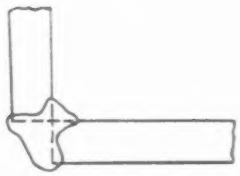
_____ b.



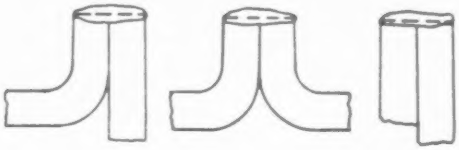
_____ c.



_____ d.

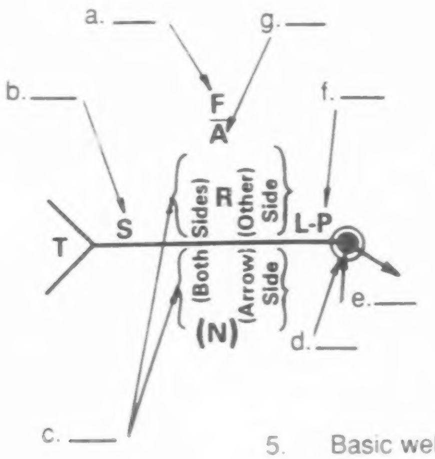


_____ e.



1. Corner joint
2. Tee joint
3. Butt joint
4. Edge Joint
5. Lap joint

37. Label parts of a welding symbol. Place the number of the symbol part in the blank that indicates its position.

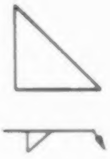


1. Groove angle
2. Finish
3. Weld-all-around
4. Size or strength of resistance welds
5. Basic weld
6. Pitch
7. Field weld

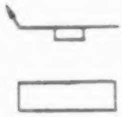
Written Test

38. Identify basic arc and gas welding symbols. Place the number of the symbol in the blank baside its illustration.

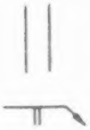
______a.



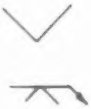
______b.



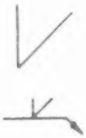
______c.



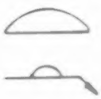
______d.



______e.



______f.



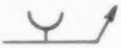
1. Bevel groove
2. Square groove
3. Fillet
4. Back or backing
5. Slot
6. V groove

Written Test

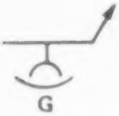
39. Solve problems concerning supplementary welding symbols. Circle the number that provides the best solution to each of the following problems.

    a. As you read specifications for a welding application you have to draw a symbol for, you note that it calls for a machined flush finish. The symbol you place on your drawing should be:

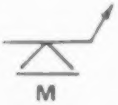
    (1)



    (2)

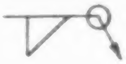


    (3)

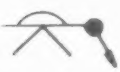


    b. As you are working on a welding application, you realize the parts cannot be welded together until they are fit together in the field. The symbol you place on your drawing should be:

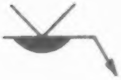
    (1)



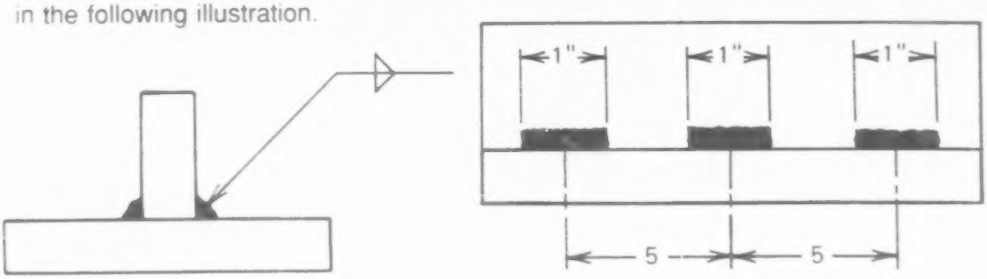
    (2)



    (3)

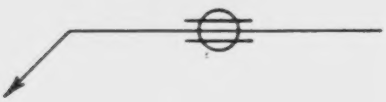


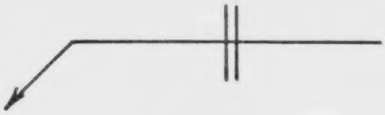
40. Use guidelines for dimensioning welds to determine the dimensions of a fillet weld. Place the dimensions for a 5/16" weld in the appropriate position on the reference line in the following illustration.



Written Test

41. Identify resistance welding symbols. Write the correct symbol name below each one of the following illustrations.





a. ____________________ b. ____________________

42. Complete statements about considerations for using adhesives for bonding materials. Circle the material that best completes each of the following statements.

  a. Before bonding adhesives are specified for use, they must first be determined functional for the (**structural**) (**environmental**) demands, and for holding and sealing.

  b. (**Chemical**) (**Biological**) considerations also figure into the selection of adhesives; they must be considered for thermosetting or thermoplastic qualities, and for repetitive structure in reaction to epoxies, polyamides, polyurathanes, and polyacrylates.

  c. Adhesive application methods must also be considered, whether the material will be applied with solvent, with a (**hot melt**) (**mop patch**) or in two parts.

  d. Another consideration for using adhesives should be the nature of the property; the application may be metal to metal, metal to plastic, or plastic to (**glass**) (**plastic**).

43. Solve a problem about considerations for joint design when using adhesive bonding. Select the answer that provides the best solution to the following problem.

You are writing specs for an adhesive application and you know the application will be subjected to cleavage. The rule you want to pay strict attention to is:

(1) When an application is subject to cleavage stress, use only a hot melt application.

(2) When an application is subject to cleavage stress, use as large a contact area as possible to assure maximum strength.

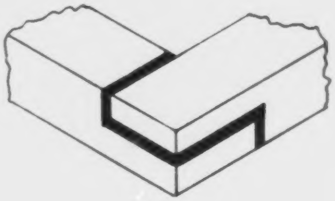
(3) When an application is subject to cleavage stress, confine it only to metal to metal applications.

Written Test

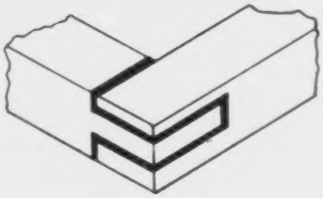
44. Identify joint designs for adhesive bonding. Place the number of the joint design in the blank beside its illustration.

1. Corner joint
2. Lap joint
3. Mortise and tenon
4. End lap joint

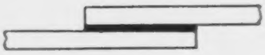
_______a.



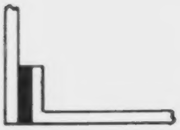
_______b.



_______c.



_______d.



45. Complete statements about CAD symbol libraries and their uses. Circle the material that best completes each of the following statements.

   a. 2D CAD symbol libraries are used to create (**top or side**) (**top or end**) views for everything from bolts to fasteners.

   b. 3D CAD symbol libraries are used to create features such as (**pockets, slots, and holes**) (**springs and washers**), and for other applications.

***Permission to duplicate this test is granted.**

Fasteners and Hardware
Unit 5

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Construct Thread Symbols Rating ______

Comments: ____

____

Assignment Sheet 2—Construct Symbols of Bolts. Screws. and Nuts Rating ______

Comments: ____

____

Assignment Sheet 3—Construct an Assembly Containing Various Fasteners Rating ______

Comments: ____

____

Assignment Sheet 4—Construct a Weldment Assembly Drawing Rating ______

Comments: ____

____

Assignment Sheet 5—Construct Spring Drawings to Include Specifications Rating ______

Comments: ____

____

Assignment Sheet 6—Construct Keys in Assembled Positions Rating ______

Comments: ____

____

Unit Evaluation Form

Assignment Sheet 7—Write Specifications For Hardware From Vendor Catalogs　　Rating ____

Comments: ____________________

____

Written Test Scores

Pretest ____　Posttest ____　Other ____

Other ____________________

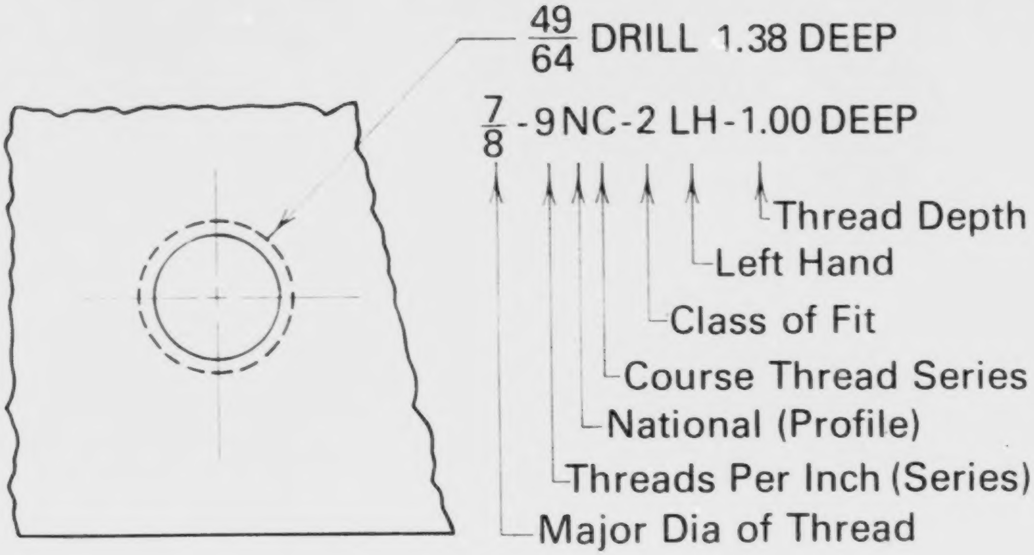
____

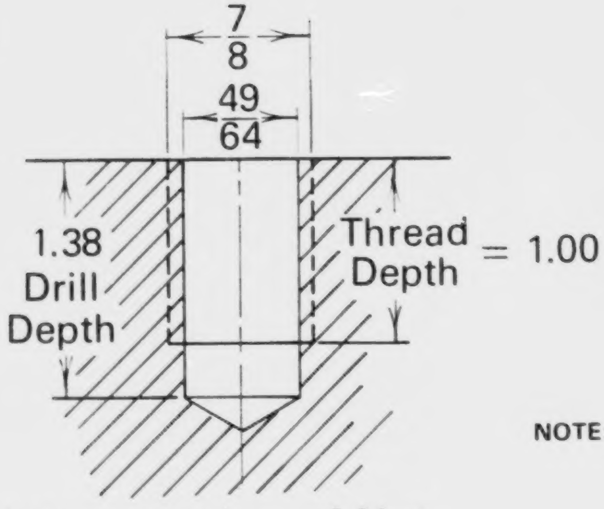
Teacher Signature ____________________ Date ________

Student Signature ____________________ Date ________

*Permission to duplicate this form is granted.

American National Thread Note for Holes

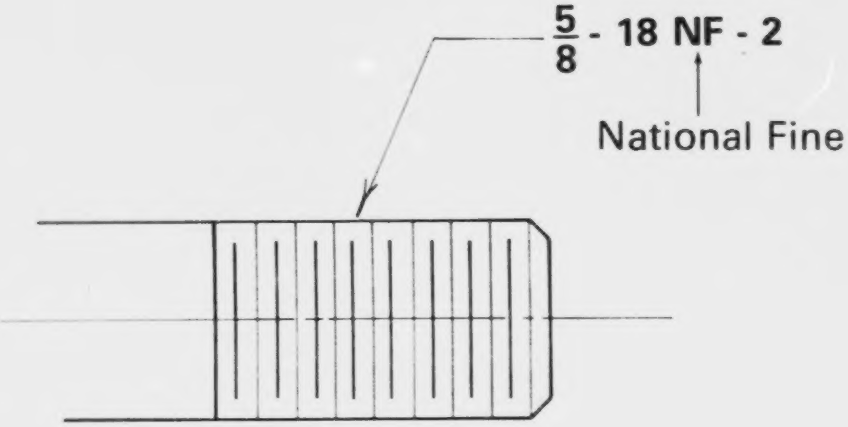

49/64 DRILL 1.38 DEEP
7/8 - 9NC-2 LH-1.00 DEEP
Thread Depth
Left Hand
Class of Fit
Course Thread Series
National (Profile)
Threads Per Inch (Series)
Major Dia of Thread

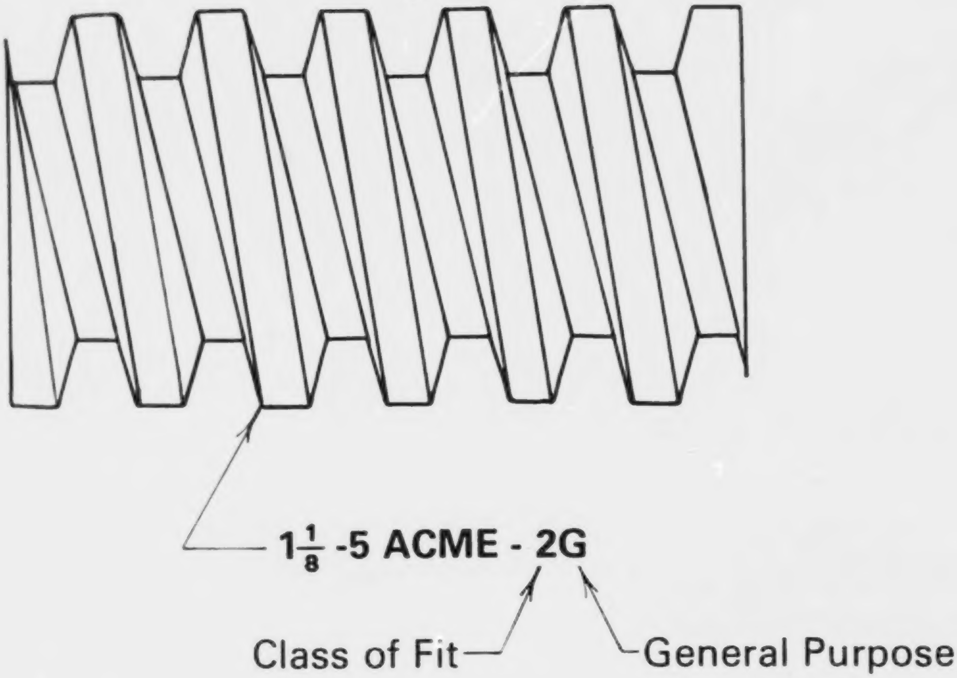

7/8
49/64
1.38 Drill Depth
Thread Depth = 1.00

Interpretation of Note

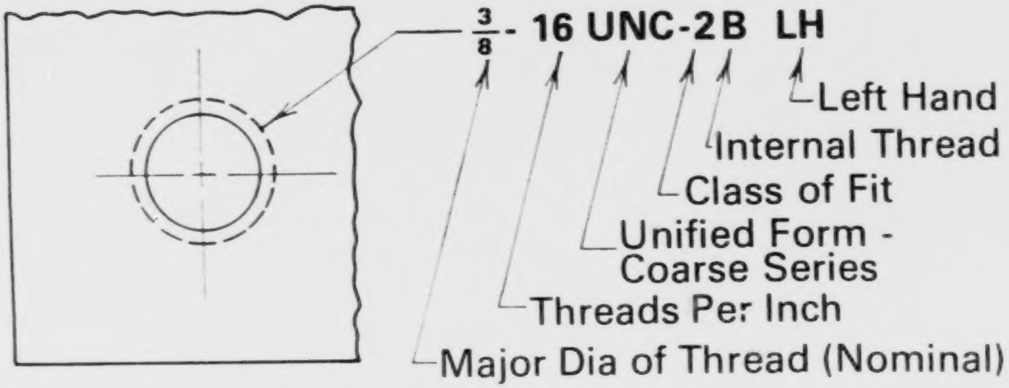
NOTE: **Obtain tap drill size from thread chart.**

American National Thread Notes for Threaded Shaft

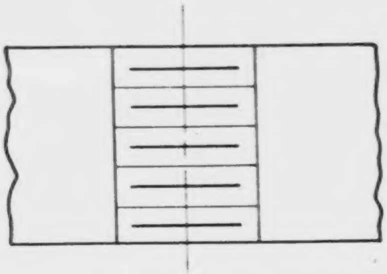

$\frac{5}{8}$ - 18 NF - 2
National Fine

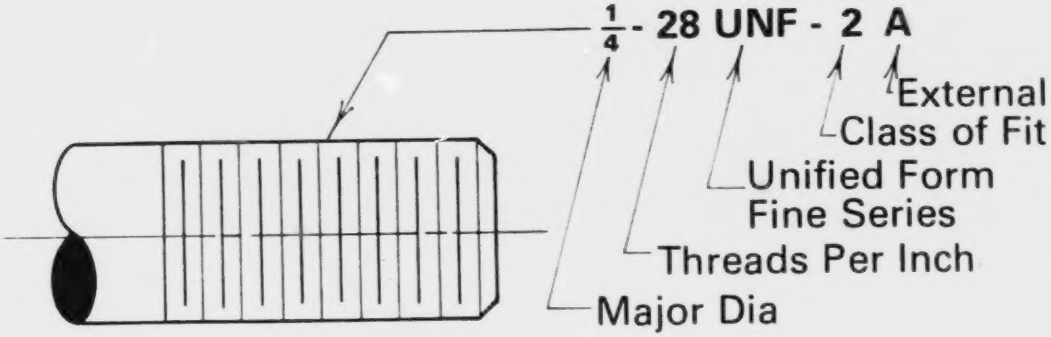

$1\frac{1}{8}$ -5 ACME - 2G
Class of Fit
General Purpose

American Standard Unified Thread Notes



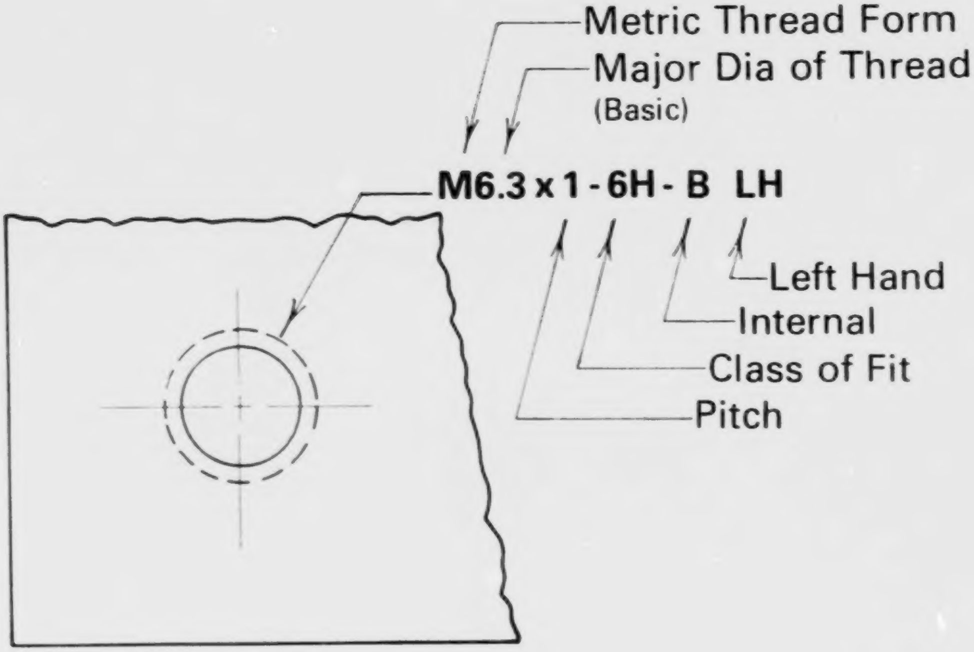
$\frac{3}{8}$ - 16 UNC-2B LH
Left Hand
Internal Thread
Class of Fit
Unified Form - Coarse Series
Threads Per Inch
Major Dia of Thread (Nominal)

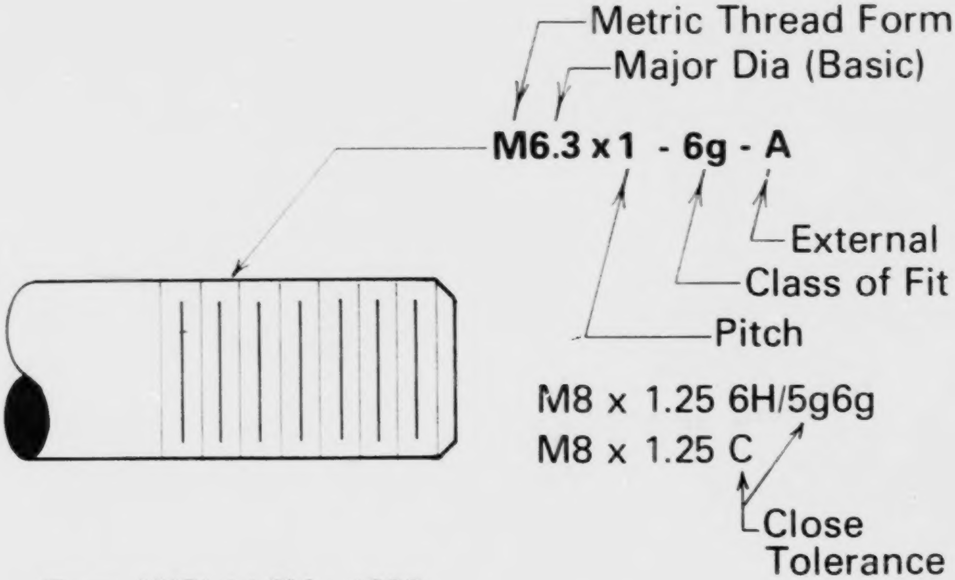




$\frac{1}{4}$ - 28 UNF - 2 A
External
Class of Fit
Unified Form Fine Series
Threads Per Inch
Major Dia

Metric Thread Notes


Metric Thread Form
Major Dia of Thread
(Basic)
M6.3 x 1 - 6H - B LH
Left Hand
Internal
Class of Fit
Pitch


Metric Thread Form
Major Dia (Basic)
M6.3 x 1 - 6g - A
External
Class of Fit
Pitch
M8 x 1.25 6H/5g6g
M8 x 1.25 C
Close
Tolerance

From ANSI 14.5M - 1982
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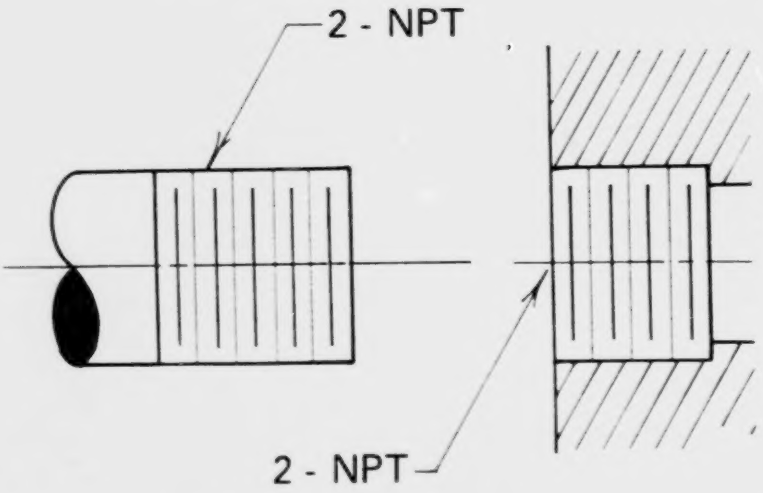
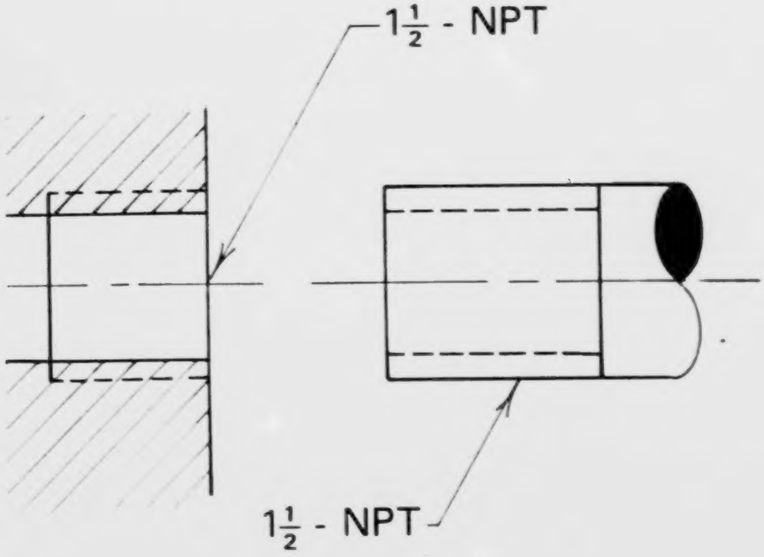
Pipe Threads



Schematic


1½ - NPT
1½ - NPT

Simplified

Fasteners and Hardware
Unit 5

Information Sheet

1. **Terms and definitions**

    a. **Fastener** — A mechanical device for holding two or more parts in a set position

    b. **Finished fastener** — A fastener made to close tolerance with a high grade finish

    c. **High strength fastener** — A fastener having high tensile and shear strength

    d. **Permanent fastener** — A fastener such as a rivet, adhesive, or weld that is not designed to be removed

    e. **Removable fastener** — A fastener such as a bolt, key, or screw which can be removed

    f. **Semi-finished fastener** — A fastener made with greater tolerances than a finished fastener with only the bearing surface and threads finished

    g. **Symbol libraries** — Standard representation of fasteners, springs, welds, and features in a CAD library

    Note: Use of CAD frees the mechanical drafter from time consuming drawing symbols by hand, but the drafter must be familiar with types of fasteners and hardware and their application.

2. **Thread nomenclatures and their meanings**

    a. **External thread** — Thread on the outside of a shaft

    b. **Internal thread** — Thread on the inside of a hole

    c. **Lead** — The distance a screw travels in one rotation

    d. **Left-hand thread** — A thread that advances when turned counterclockwise

    e. **Multiple threads** — A thread having more than one start with the lead equal to a multiple of the pitch

    f. **Right-hand thread** — A thread that advances when turned clockwise

    g. **Series of thread** — The number of threads per inch based on standard nominal diameters

Information Sheet

h. **Single thread** — A thread having one start with the lead equal to the pitch

i. **Feature** — A hole, slot, or special shape in 2D or 3D produced by hand drawing or CAD

Example: A feature in CAD may be a counter bored hole with the drill diameter, counter bore diameter, counter bore depth and drill hole depth stored in the symbol. When dimensioning the symbol the note is automatically generated from the feature information.

3. **Other fasteners and their applications**

a. **Adhesive** — Chemical bonding between parts

b. **Hardware** — Small parts such as fasteners, springs, and washers

c. **Keys** — Devices used to attach wheels, pulleys, and gears to shafts

d. **Nuts** — Devices for fastening, adjusting, and transmitting motion or power

e. **O-Rings** — Devices used to seal along a shaft

f. **Pins** — Devices used for semi-permanent attachment or location

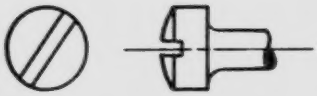
g. **Retaining rings** — Devices with removable shoulders so they can accurately retain, locate, or lock components in bases, housings, or on shafts

h. **Washers** — Devices that insulate, lubricate, span large holes, or distribute stress over a larger area

i. **Welding** — The joining of parts by melting base metal to form a unit structure to support a load

4. **Types of screw heads and their uses**

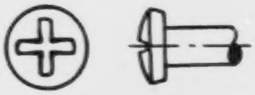
a. Slotted heads are used with flat blade screwdrivers and are used just about everywhere, around the house and in industry where service requirements do not require extra strength.



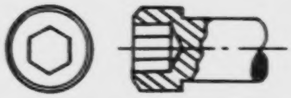
Information Sheet

b. Recessed heads have a centered indentation that permits them to be used with a special type of screwdriver; the most common are the cross or Phillips head, the socket head, and the clutch head.

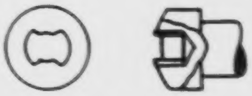
Note: Recessed heads are used most frequently in industrial applications because their design affords greater strength.



Cross (Phillips)



Socket



Clutch

5. Screw thread nomenclature

a. The crest, root, and side are names that help define the thread size and shape on a screw.

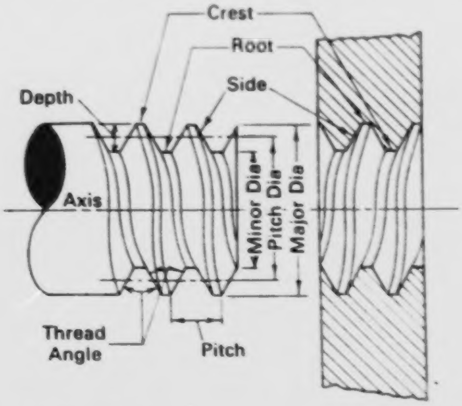
b. Diameter is used to define screw thickness at various points of the screw, namely, major diameter, pitch diamter, and minor diameter.

c. Depth refers to the distance from the major diameter to the point of the minor diameter.

d. Axis refers to the imaginary straight line around which the thread is designed.

e. Thread angle is the angle formed by one side as measured from the center of the depth of the screw.

f. Pitch is a word used often in mechanical drafting because it is in frequent use when working with screws; pitch means the distance from one crest to the next crest as measured parallel to the axis of the screw.

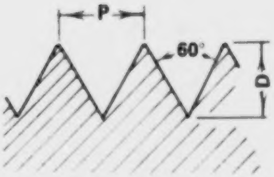


External Thread Internal Thread

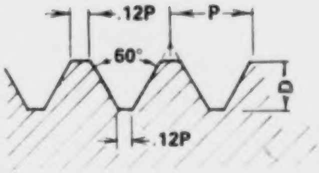
Information Sheet

6. Screw thread profiles

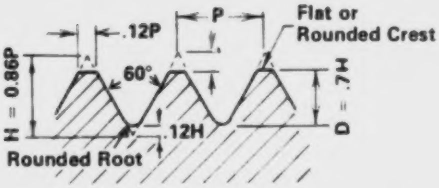
a. Sharp V—Adjustments



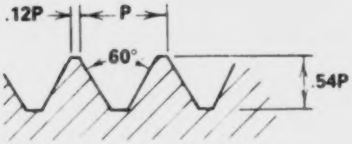
b. American National—General purpose


.12P
P
60°
D
.12P

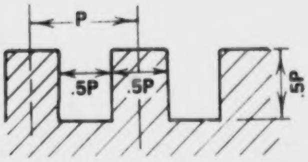
c. Unified


.12P
P
Flat or Rounded Crest
60°
H = 0.86P
D = .7H
.12H
Rounded Root

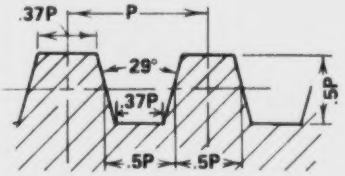
d. Metric



e. Square

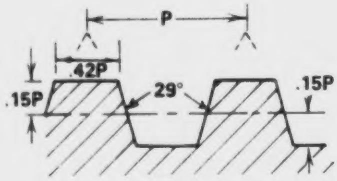


f. Acme—General purpose

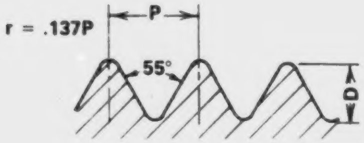

.37P
P
29°
.37P
.5P
.5P
.5P

Information Sheet

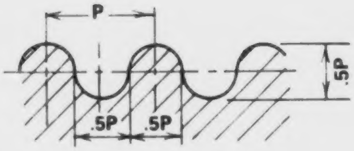
g. Acme—Stub



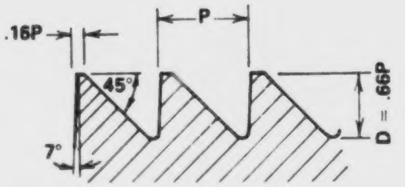
h. Whitworth Standard



i. Knuckle



j. Buttress



7. **Guidelines for computing thread leads**

a. Since lead means the actual distance a screw thread advances in one revolution, a single thread lead is the same as the pitch.

Example: 1/4 - 20UNC pitch = 1/4 = .25

L = LEAD = PITCH = .25

b. Computing a double thread lead means the lead is two times the pitch, and computing a triple thread lead means the lead is three times the pitch.

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c. Computing multi-thread leads requires dividing the number of threads by the pitch; the formula is: $\text{Pitch} = \dfrac{1}{\text{Number of threads per inch}}$

Example: For a screw that has 12 threads per inch, use pitch to compute single and double leads.

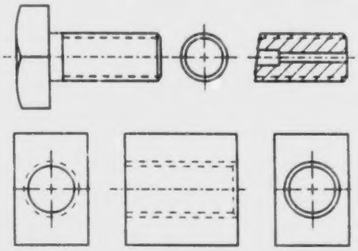
Pitch = 1/12
L = Lead = 1/12 for single thread
L = Lead = 2/12 or 1/6 for double thread

8. Ways of presenting screw heads

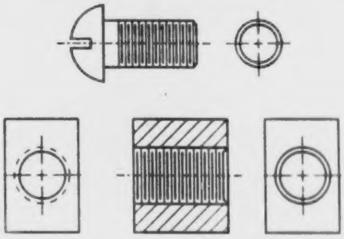
a. To draw screw threads as they actually appear would consume a great deal of a drafter's time, so there are various methods of presenting screw threads in drawings.

Note: Company design and drafting standards determine thread representation.

b. Presenting threads with the **simplified method** may be the quickest method of all; the thread depth is shown as a dashed line running parallel to the axis, and this method is acceptable for many applications.

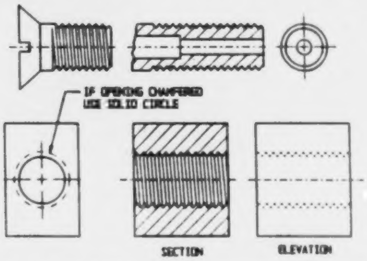


c. Presenting threads with the **schematic method** is also a time saver and acceptable for many applications; the crest and root lines are spaced to give the drawing better representation than the simplified method.



Information Sheet

d. Presenting threads withe the **detailed method** is not often done because the method presents threads the way they appear to the human eye, and it is time consuming to draw them this way, even at a CAD workstation.



Note: Threads may be presented with combinations of the three methods.

9. Classes of fit for unified and metric threads and their applications

a. Class 1A and 1B unified threads—Used for parts that are easy to assemble or quick to assemble; also used for ordinance and other special uses

Note: "A" refers to internal and "B" refers to external.

b. Class 2A and 2B unified threads—Used for general purpose applications; most common uses

c. Class 3A and 3B unified threads—Used for applications specifying close tolerances

d. Coarse or general purpose metric threads—Used for UNC or NC; these are preferred by most commercial users

e. Fine metric threads—Used for UNF or NF

10. Parts of thread notes for American National screw threads

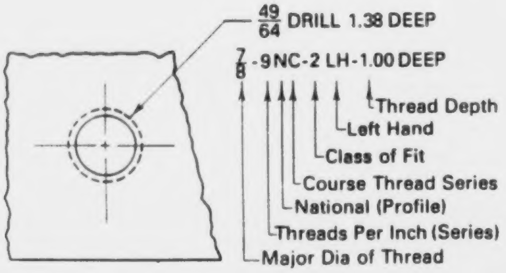
a. Notes should read left to right starting with the major diameter of the thread, threads per inch, profile, series, class of fit, left hand, and thread depth.

b. Specifications for drill size and depth should also be given if required.

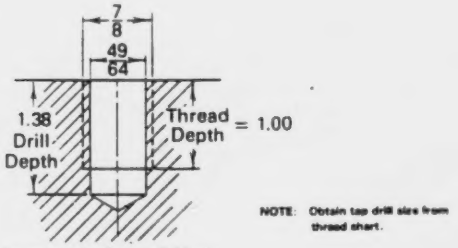
c. Thread notes for American National threaded shaft should show major diameter, threads per inch, series, and class of fit.

Information Sheet

American National Thread Note for Holes



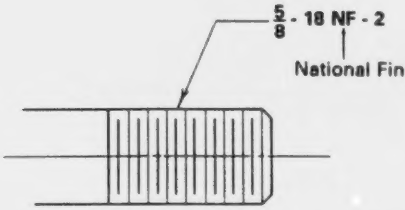
$\frac{49}{64}$ DRILL 1.38 DEEP
$\frac{7}{8}$-9NC-2 LH-1.00 DEEP
Thread Depth
Left Hand
Class of Fit
Course Thread Series
National (Profile)
Threads Per Inch (Series)
Major Dia of Thread



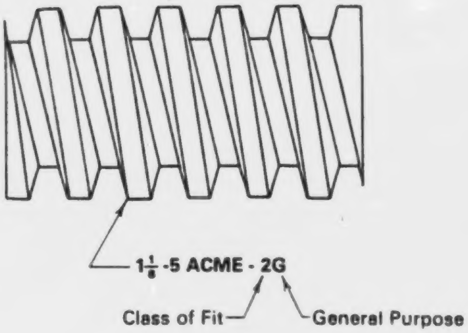
$\frac{7}{8}$
$\frac{49}{64}$
1.38 Drill Depth
Thread Depth = 1.00
NOTE: Obtain tap drill size from thread chart.

Interpretation of Note

American National Thread Notes for Threaded Shaft



$\frac{5}{8}$ - 18 NF - 2
National Fine

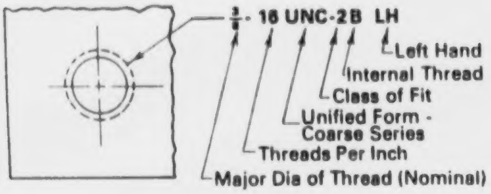


$1\frac{1}{8}$ -5 ACME - 2G
Class of Fit
General Purpose

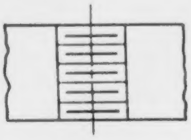
11. **Parts of thread notes for American National Standard Unified screw threads**

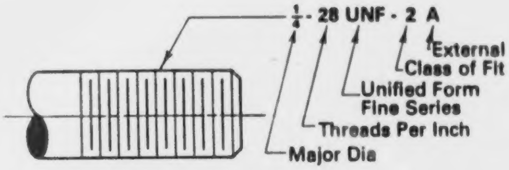
    a. Notes should read left to right starting with the major diameter of the thread, threads per inch, series, class of fit, internal or internal thread, and left hand indication, if specified.

American Standard Unified Thread Notes



$\frac{3}{8}$- 16 UNC-2B LH
Left Hand
Internal Thread
Class of Fit
Unified Form - Coarse Series
Threads Per Inch
Major Dia of Thread (Nominal)





$\frac{1}{4}$- 28 UNF - 2 A
External
Class of Fit
Unified Form Fine Series
Threads Per Inch
Major Dia

Information Sheet

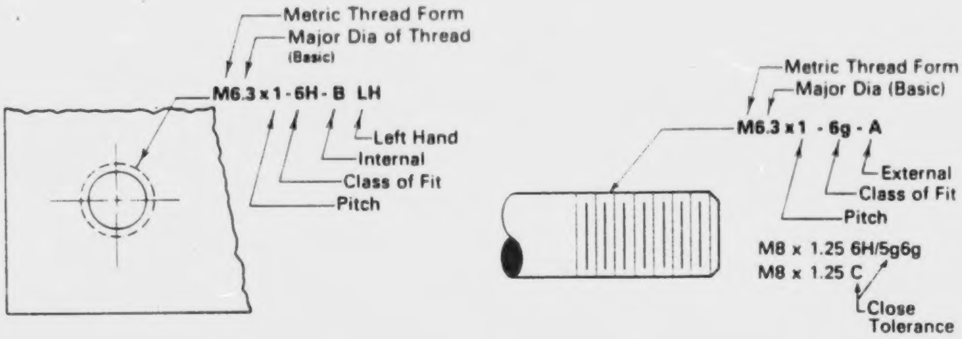
12. Parts of thread notes for metric screw threads

a. Notes should read left to right starting with the metric thread form, the major diameter, pitch, class of fit, internal or external indication, and left hand indication, if required.

b. Notes for metric threaded shafts should read left to right starting with the metric thread form, the major diameter, pitch, class of fit, and external or internal indication.

c. Close tolerances should be indicated in a separate entry.

Metric Thread Notes

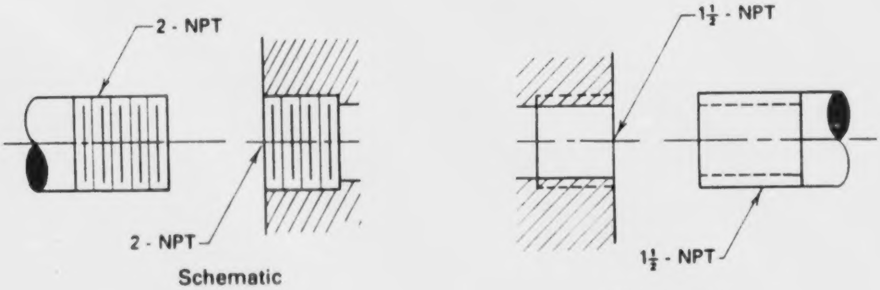

Metric Thread Form
Major Dia of Thread (Basic)
M6.3 x 1 - 6H - B LH
Left Hand
Internal
Class of Fit
Pitch
Metric Thread Form
Major Dia (Basic)
M6.3 x 1 - 6g - A
External
Class of Fit
Pitch
M8 x 1.25 6H/5g6g
M8 x 1.25 C
Close Tolerance

13. Ways to present pipe threads

a. Pipe threads may be presented in schematic form or in simplified form.

b. Pipe thread notes should contain diameter and pipe class.

Pipe Threads

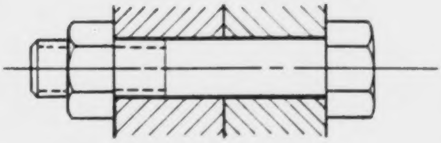

2 - NPT
2 - NPT
$1\frac{1}{2}$ - NPT
$1\frac{1}{2}$ - NPT

Schematic

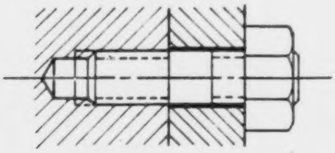
Simplified

14. Types of threaded removable fasteners

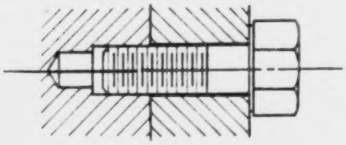
a. Bolt



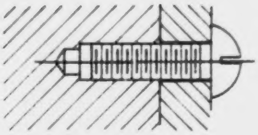
b. Stud



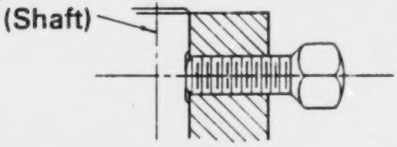
c. Cap screw



d. Machine screw

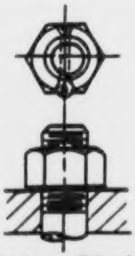


e. Set screw

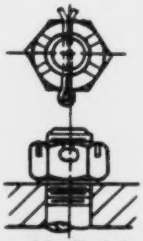


15. Types of locknuts and locking devices

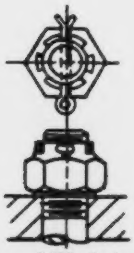
a. Nuts that lock with cotter pins



Cotter Pin Hex Semi-Finished Thick Nut



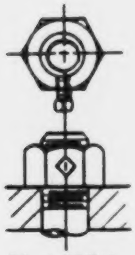
Hex Unfinished Slotted Nut With Cotter Pin

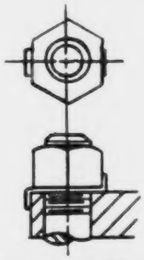


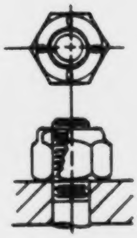
Semi-Finished Castle Nut With Cotter Pin

Information Sheet

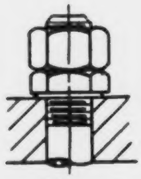
b. Nuts that lock with other devices or design

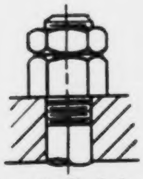

Nut With Set Screw


Hexagon Nut with Lock

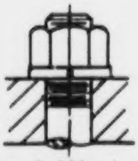

Stop Nut

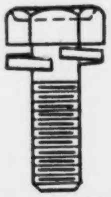
c. Jam nuts

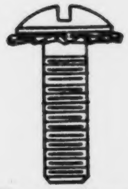

Hex Semi-Finished Jam Nut

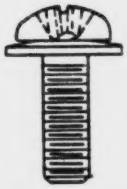

Hex Unfinished Jam Nut

d. Screw and washer assemblies


Lock Washer


Hexagon Head Screw and Spring Lock Washer


Truss Head Screw and External Tooth Lock Washer


Pan Head Screw and Conical Spring Washer

e. Other types of locking nuts

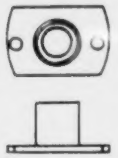
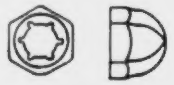
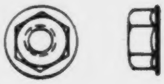
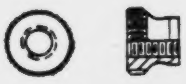
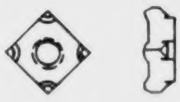


Plate Nut


Stamped Nut

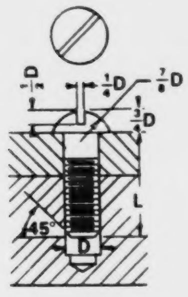

Flange Nut


Knurled Nut

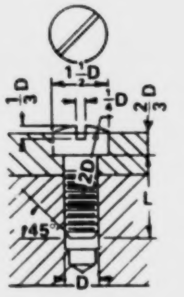

Weld Nut

16. Types of standard cap screws

a. Round head and fillister head

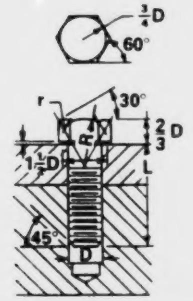

$\frac{1}{2}$D
$\frac{1}{4}$D
$\frac{7}{8}$D
$\frac{3}{4}$D
L
45°
D

Round Head

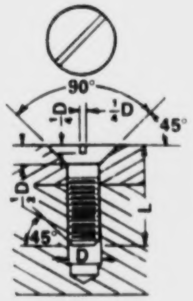

$1\frac{1}{2}$D
$\frac{1}{3}$D
$\frac{1}{4}$D
$\frac{2}{3}$D
2D
L
45°
D

Fillister Head

b. Hexagon head and flat head

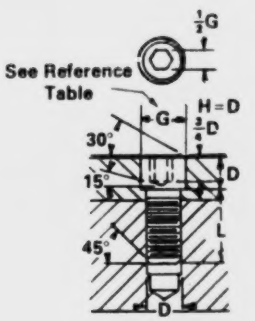

$\frac{3}{4}$D
60°
r
30°
$\frac{2}{3}$D
R
$1\frac{1}{2}$D
L
45°
D

Hexagon Head

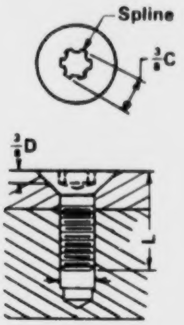

90°
$\frac{1}{4}$D
$\frac{1}{4}$D
45°
$\frac{1}{3}$D
L
45°
D

Flat Head

c. Hex socket and spline socket flat head


$\frac{1}{2}$G
See Reference Table
G
H=D
$\frac{3}{4}$D
30°
D
15°
L
45°
D

Hex Socket

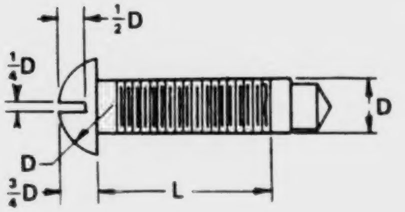

Spline
$\frac{3}{8}$C
$\frac{3}{4}$D
L

Spline Socket
Flat Head

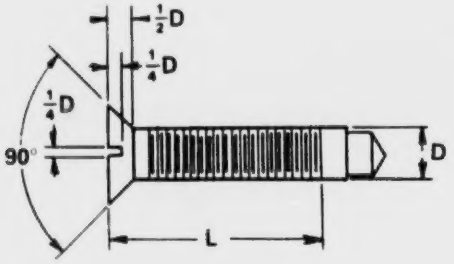
Information Sheet

17. Types of machine screws

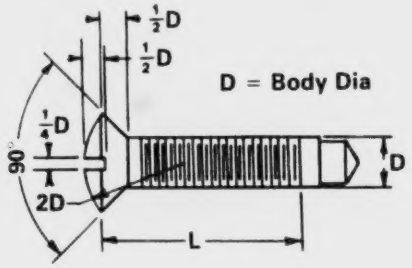
a. Round head


$\frac{1}{2}$D
$\frac{1}{4}$D
D
D
$\frac{3}{4}$D
L

b. Flat head

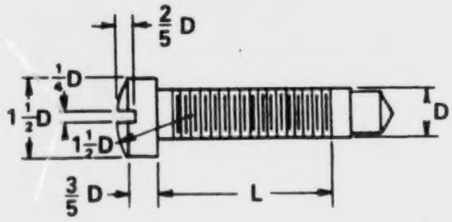

$\frac{1}{2}$D
$\frac{1}{4}$D
$\frac{1}{4}$D
90°
D
L

c. Oval head


$\frac{1}{2}$D
$\frac{1}{2}$D
$\frac{1}{4}$D
90°
2D
D
L

D = Body Dia

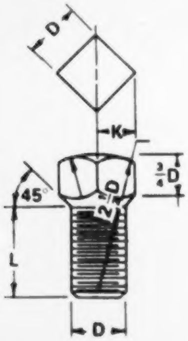
d. Fillister head


$\frac{2}{5}$ D
$\frac{1}{4}$D
1$\frac{1}{2}$D
1$\frac{1}{2}$D
D
$\frac{3}{5}$ D
L

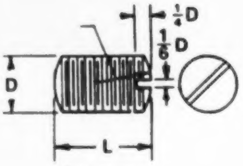
Information Sheet

18. Types of heads and points on set screws

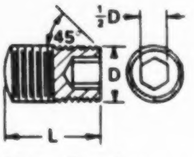
a. Standard set screw heads include: square head, slotted, hex socket, and socket spline.


D
K
45°
$\frac{3}{4}$D
$\frac{D}{2}$
L
D

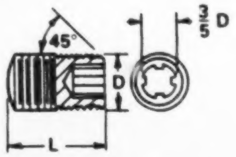
Square Head


$\frac{1}{4}$D
$\frac{1}{6}$D
D
L

Slotted

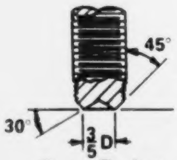

$\frac{1}{2}$D
45°
D
L

Hex Socket

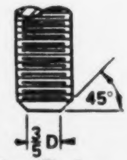

$\frac{3}{5}$D
45°
D
L

Socket Spline

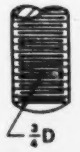
b. Standard set screw points include: cup point, flat point, oval point, full dog point, half dog point, and cone point.


45°
30°
$\frac{3}{5}$D

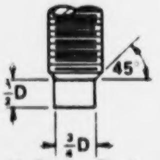
Cup Point



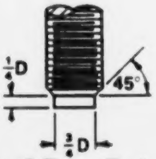
Flat Point



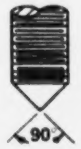
Oval Point


45°
$\frac{1}{2}$D
$\frac{3}{4}$D

Full Dog Point


$\frac{1}{4}$D
45°
$\frac{3}{4}$D

Half Dog Point



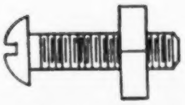
Cone Point

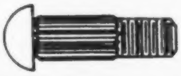
D = Thread Diameter
L = Length

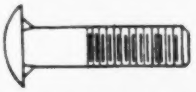
Information Sheet

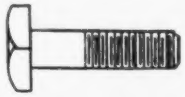
19. Miscellaneous bolts, nuts, and screws

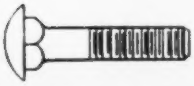
a. Bolts are generally identified by head shape as square, hex, round, or oval, and the thread design that usually defines the design purpose of the bolt; bolt selection ranges from common stove bolts with very general applications to rivet head bolts with specific applications.

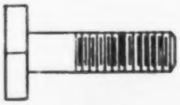

Stove Bolt

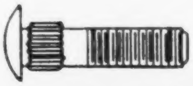

Rivet Bolt

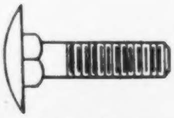

Round Head Fin Neck Bolt

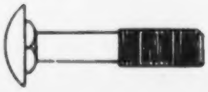

Square Head Bolt

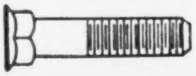

Round Head Square Neck Bolt

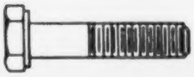

T-Bolt

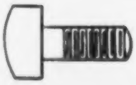

Round Head Ribbed Neck Bolt

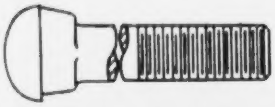

Step Bolt

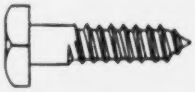

Round Head Short Square Neck Bolt

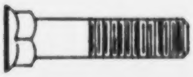

Square Neck

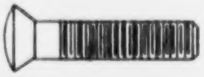

Hexagon Head


Meter Bolt


Oval Head Truck Bolt

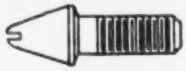

Lag Bolt

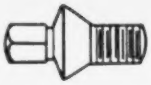

Round Countersunk Head Square Neck Plow Bolt

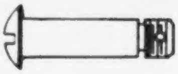

Strut Bolt

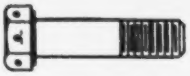
Information Sheet

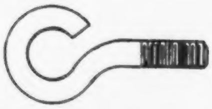
b. Other bolts are named for the way they look or their special applications such a the hood latch bolt, boiler patch bolt, or the clevis bolt or aircraft drilled head bolt that are designed for use with locking cotter pins.

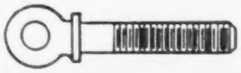

Hood Latch Bolt

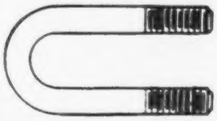

Boiler Patch Bolt

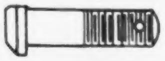

Clevis Bolt


Aircraft Drilled Head Bolt

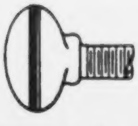

Eye Bolt, Open Anchor Ring

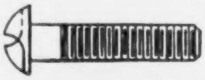

Collared Eye Bolt

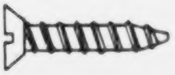

U-Bolt, Round Bend


Connecting Rod Bolt

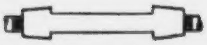
c. Screws vary in design according to their intended applications such as the thumb screw frequently used as an adjusting device on instruments or tools.

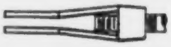

Thumb Screw

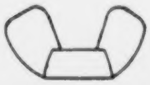

One-Way Head Screw


Tapping Screw

d. The clevis, turnbuckle, and wing nut are other special purpose devices.


Turnbuckle

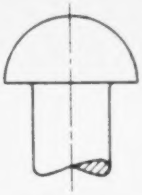

Clevis


Wing Nut

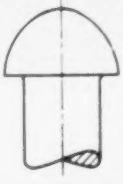
Information Sheet

20. Standard large and small rivets

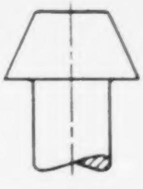
a. Standard large rivets include the button head, the high button head or acorn, the cone head, the pan head, and the heavy duty flat top countersunk and round top countersunk.



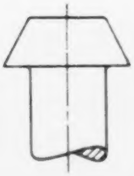
Button Head



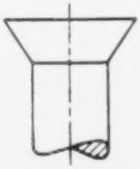
High Button Head (Acorn)



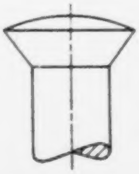
Cone Head



Pan Head

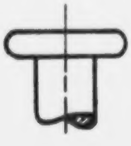


Flat Top Countersunk HD

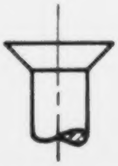


Round Top Countersunk HD

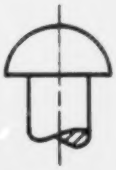
b. Standard small rivets include the flat head, countersunk head, button head, pan head, and the truss or wagon box head.



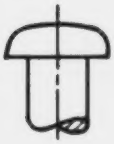
Flat Head



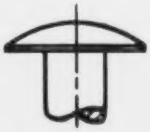
Countersunk Head



Button Head



Pan Head

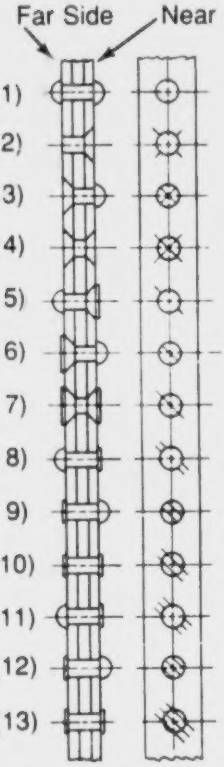


Truss or Wagon Box Head

Information Sheet

21. Conventional rivet symbols and their meanings

a. Shop rivets



(1) —Two full heads

(2) —Countersunk and chipped; near side

(3) —Countersunk and chipped; far side

(4) —Countersunk and chipped; both sides

(5) —Countersunk not over 1/8″ high; near side

(6) —Countersunk not over 1/8″ high; far side

(7) —Countersunk not over 1/8″ high; both sides

(8) —Flattened to 1/4″, 1/2″ and 5/8″ rivets and over; near side

(9) —Flattened to 1/4″, 1/2″ and 5/8″ rivets and over; far side

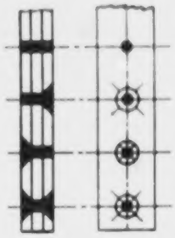
(10) —Flattened to 1/4″, 1/2″ and 5/8″ rivets and over; both sides

(11) —Flattened to 3/8″, 3/4″ rivets and over; near side

(12) —Flattened to 3/8″, 3/4″ rivets and over; far side

(13) —Flattened to 3/8″, 3/4″ rivets and over; both sides

b. Field rivets



(1) —Two full heads

(2) —Countersunk; near side

(3) —Countersunk; far side

(4) —Countersunk; both sides

Information Sheet

22. Advantages of plastic fasteners over metal fasteners

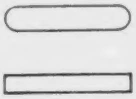
a. Plastic fasteners are lighter weight than metal fasteners, and plastic fasterners are corrosion resistant.

b. Plastic fasteners make excellent thermal and electrical insulators, and they are easy to color code.

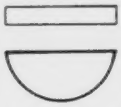
23. Shaft locking hardware

a. As the name implies, shaft locking hardware consists of devices designed to lock a component onto a shaft.

b. Common locking hardware includes keys of various kinds, including the round end key, the Woodruff key, the square key, the flat key, the taper key, and the gib head key.



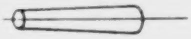
Round End Key (Pratt and Whitney)



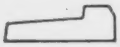
Woodruff Key

Square Key

Flat Key

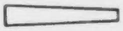


Taper Key

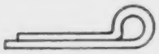


Gib Head Key

c. Common locking hardware also includes pins such as the taper pin and the cotter pin.

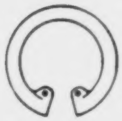


Taper Pin

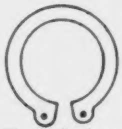


Cotter Pin

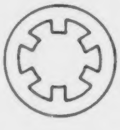
d. Other locking hardware includes a variety of rings and triangles designed for both internal and external applications.



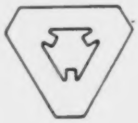
Retaining Ring Interna!



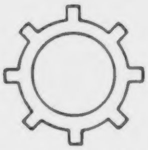
Retaining Ring External



Self Locking External



Self Locking Triangular

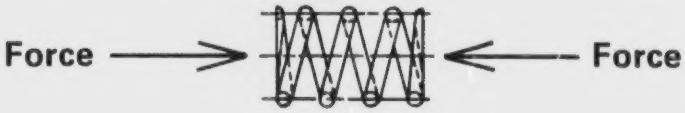


Self Locking Internal

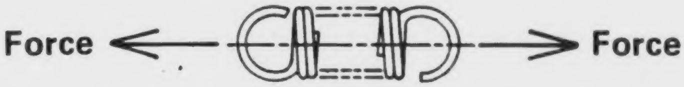
Information Sheet

24. **Types of springs and their characteristics**

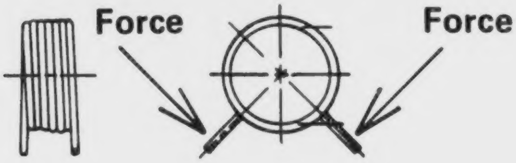
a. **Compression**—Used to absorb or cushion forces


Force
Force

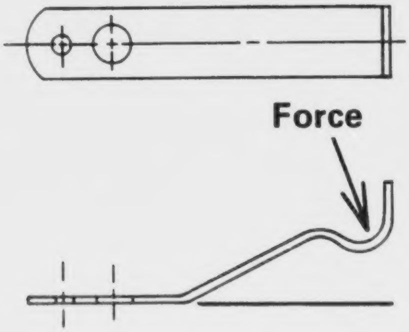
b. **Extension**—Used in applications where they stretch and pull back to an original position


Force
Force

c. **Torsion**—Used in many different shapes that involve twisting


Force
Force

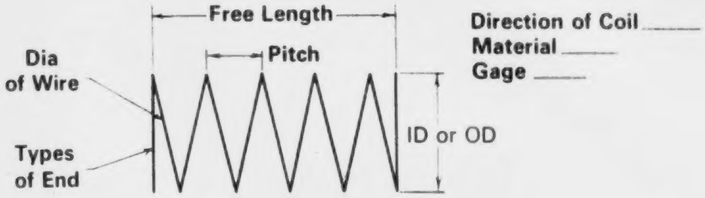
d. **Flat**—Used in a variety of shapes that absorb energy



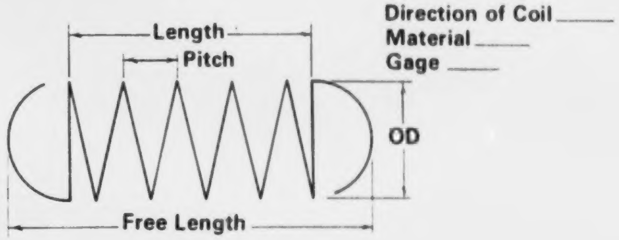
Information Sheet

25. Notes and dimensions for types of springs

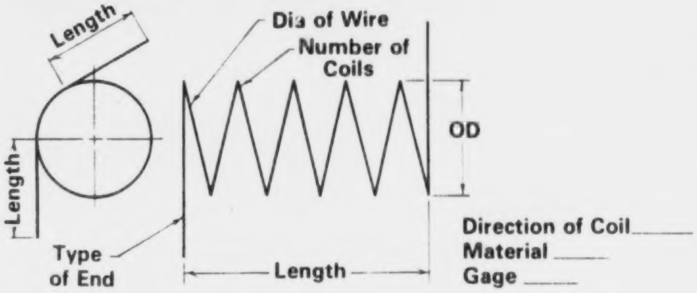
a. Notes for compression springs should show diameter of wire and types of ends, the free length and the pitch in the interior of the drawing, ID or OD to the immediate right, and direction of coil, material, and gage noted on the drawing.


Free Length
Pitch
Dia of Wire
Types of End
ID or OD
Direction of Coil _____
Material _____
Gage _____

b. Notes for extension springs should show the free length to external ends, the length and pitch in the interior of the drawing, the OD, and direction of coil, material, and gage noted on the drawing.


Length
Pitch
Direction of Coil _____
Material _____
Gage _____
OD
Free Length

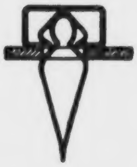
c. Notes for torsional springs should show length dimensions in a separate entry on the end view, type of end length, OD and diameter or wire, and number of coils, and entries for direction of coil, material, and gage noted on the drawing.


Length
Dia of Wire
Number of Coils
OD
Length
Type of End
Length
Direction of Coil _____
Material _____
Gage _____

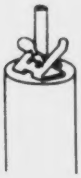
Information Sheet

26. Types of spring clips and their designs

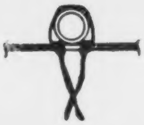
a. Spring molding clip



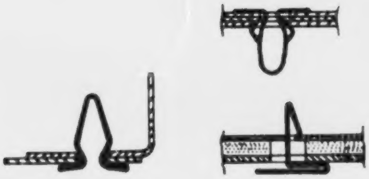
b. Stud receiver clip



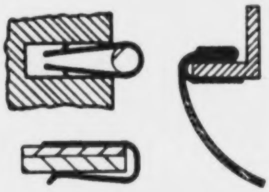
c. Cable, wiring, and tubing clips



d. Dart-type clips



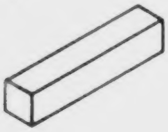
e. U-shaped, S-shaped, and C-shaped clips



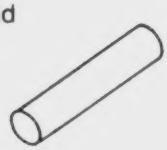
Information Sheet

27. **Types of keys designed to prevent relative motion between wheel and shaft**

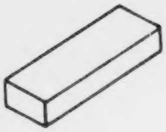
    a. Square



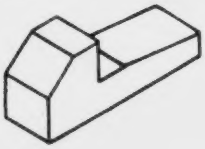
    b. Round



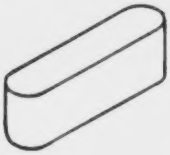
    c. Flat



    d. Gib head

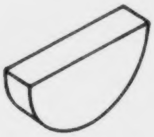


    e. Pratt and Whitney



    f. Woodruff

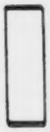
    Note: Woodruff keys are ordered by number; other keys are ordered by size.



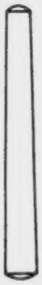
information Sheet

28. Types of machine pins

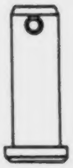
a. machine pins in common use are dowel, tapered, clevis, and split.



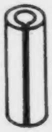
Dowel



Tapered

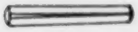


Clevis

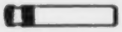


Split

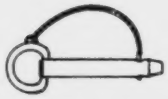
b. Other types of machine pins include drive, grooved, knurled, wire, cotter, and quick release.



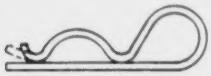
Grooved



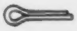
Knurled



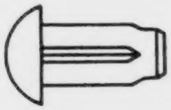
Quick Release



Wire

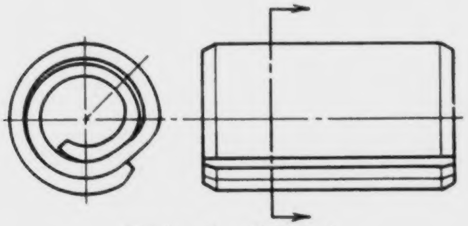


Cotter



Drive

c. Another machine pin type is the spirally coiled pin.

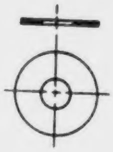


Spirally Coiled

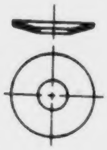
Information Sheet

29. Types of washers and their applications

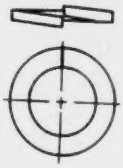
a. **Flat washers**—Used on bearing surfaces for heavy or standard applications



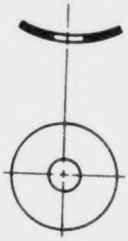
b. **Conical washers**—Used in conjunction with spring action



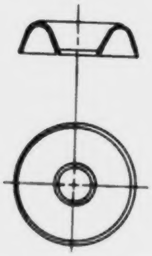
c. **Helical spring washers**—Used for locking applications



d. **Spring washers**—Used for built-in pressure applications



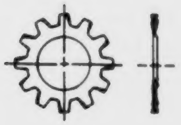
e. **Special purpose washers**—Used in plated or unplated varieties for decoration and other craft applications



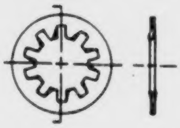
Information Sheet

30. Types of tooth lock washers

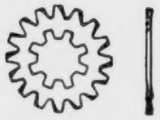
a. Internal, external, and external-internal



External

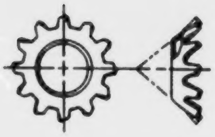


Internal

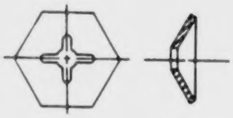


External-Internal

b. Countersunk and pyramidal



Countersunk



Pyramidal

31. Insert characteristics and their industrial applications

a. **Light alloys and plastics**—Inserts add higher strength

b. **Ferrous alloys**—Inserts are used to make permanent threads

c. **Thin parts**—Inserts are used for internal locking of threaded holes

d. **Reassembly**—Inserts permit mating screw reassembly without damage to metal

32. Industrial applications of spring washer designs

a. Spring washers are designed to provide pressure on adjacent parts.

b. Spring washers can act as take-up devices in an assembly.

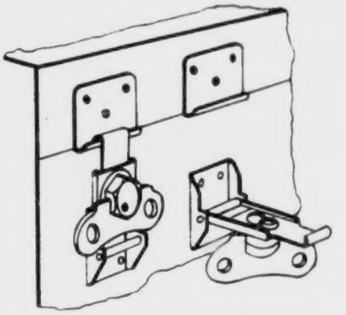
c. Spring washers can control end pressure.

d. Spring washers are used to eliminate end play.

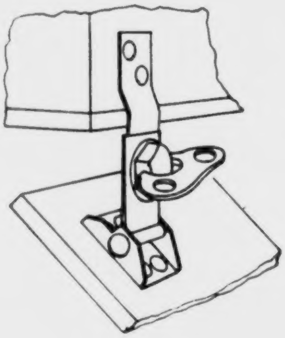
Information Sheet

33. Quick opening and quick locking devices

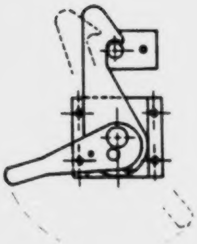
a. Link, hinge, and hook locks



Link Lock

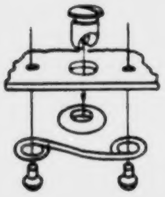


Hinge Lock



Hook Lock

b. Quarter turn, spring lock, and trigger lock

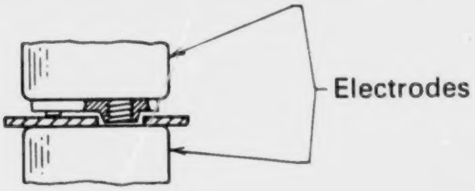


Quarter Turn

34. Miscellaneous machine elements and their uses

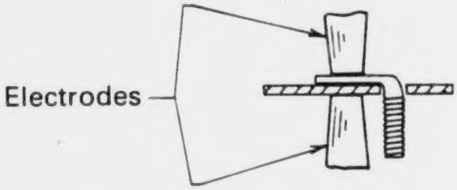
a. **Quick release pins**—Permit rapid assembly and disassembly of parts

b. **Projection weld**—A resistance weld process used to weld nuts to a surface



Information Sheet

c. **Spot weld**—A resistance weld process used to weld studs to a surface



d. **Stud weld fasteners**—Help prevent leaks at joints

e. **Self-tapping screws**—Used to cut mating threads in metal or plastic

f. **Captive nuts**—Help prevent nuts from rotating

g. **Wing nuts**—Permit manual fastening with fingers

h. **Screw and washer assemblies**—Save time at assembly

35. **Advantages of welding instead of using threaded fasteners**

    a. Welding saves both time and expense because welding processes are fast and relatively simple.

    b. In most cases, welding produces less weight than a casting or forged part.

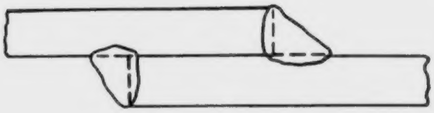
    c. Welding produces less noise and leaves a neater appearance.

    d. Welding makes painting easier.

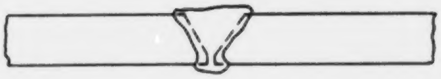
    e. All in all, welding is a good process for small quantity jobs.

36. **Basic types of welded joints**

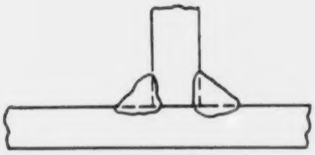
    a. Lap joint



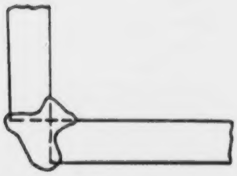
b. Butt joint



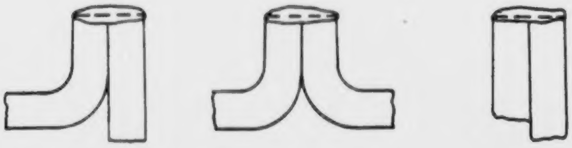
c. Tee joint



d. Corner joint



e. Edge joint



37. Parts of a welding symbol

a. The central focus of welding symbol is the reference line which has an arrow connecting it to the arrow side of the weld.

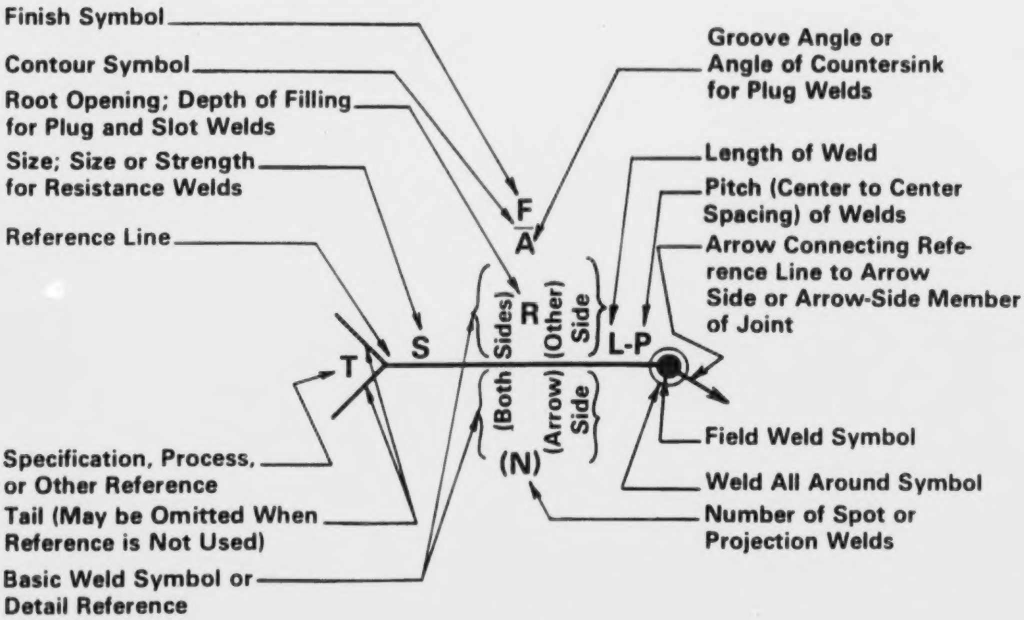
b. The basic weld symbol or detail reference will be on the arrow side of the reference line or the other side.

c. All information essential to groove angle, root opening, and even how to finish the weld appear above the reference line at location R.

Information Sheet

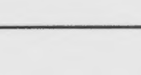
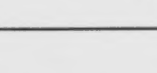
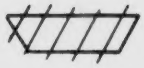
d. On the right side of the reference line, such things as the length of the weld, pitch or center to center spacing of welds, and such things as the weld all around symbol, or a field weld symbol are found.

Note: Field weld means the weld is made on site rather than in the shop.


Finish Symbol
Contour Symbol
Root Opening; Depth of Filling for Plug and Slot Welds
Size; Size or Strength for Resistance Welds
Reference Line
Specification, Process, or Other Reference
Tail (May be Omitted When Reference is Not Used)
Basic Weld Symbol or Detail Reference
Groove Angle or Angle of Countersink for Plug Welds
Length of Weld
Pitch (Center to Center Spacing) of Welds
Arrow Connecting Reference Line to Arrow Side or Arrow-Side Member of Joint
Field Weld Symbol
Weld All Around Symbol
Number of Spot or Projection Welds
F
A
R
S
T
L-P
(N)
(Both Sides)
(Other) Side
(Arrow) Side

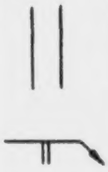
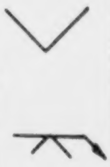
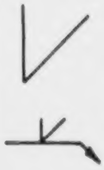
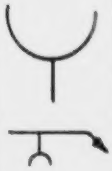
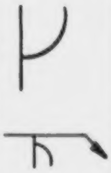
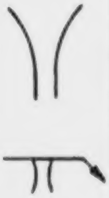
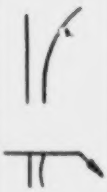
38. Basic arc and gas welding symbols

a. Basic weld symbols include the fillet, plug or slot, and arc-spot or arc-seam symbols.

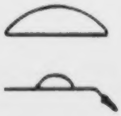
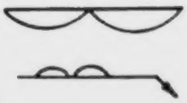
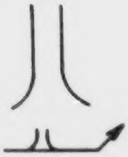
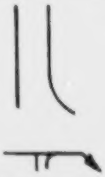
Fillet	Plug or Slot	Arc - Spot or Arc - Seam
	 Old	Old 

Information Sheet

b. There are seven different types of groove welds, and each type has its own symbol, and the sumbol reflects the general shape of the groove weld.

Groove						
Square	V	Bevel	U	J	Flare V	Flare Bevel
						

c. Other important weld symbols are for the back or backing weld, surfacing, and the flange welds on edges and corners.

Back or Backing	Surfacing	Flange	
		Edge	Corner
			

39. Supplementary welding symbols

a. Supplementary symbols usually concern instructions about how the weld should be completed, where it should be completed, and how it should be finished.

b. The basis supplementary symbols are: weld all around, field weld, melt through, and the contour symbols for flush, convex, and concave.

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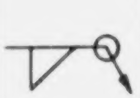
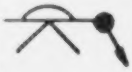
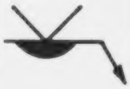
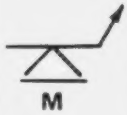
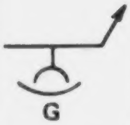
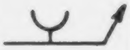
c. The letter M for machine and G for grind are included to indicate degree of finishing.

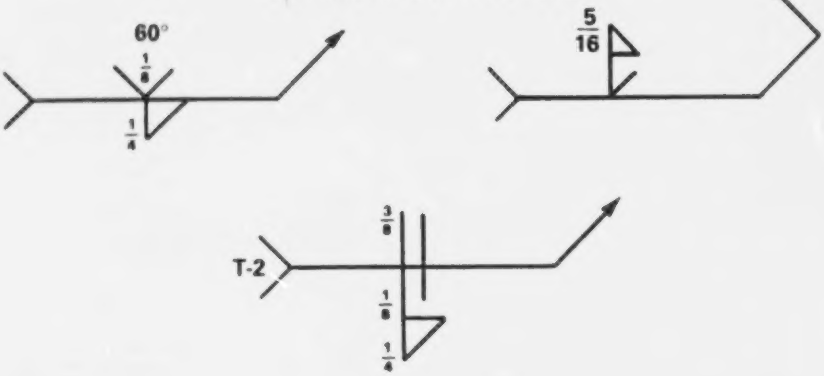
Weld All Around	Field Weld	Melt Thru	Contour		
			Flush	Convex	Concave
○	●	◒	—	⌒	◡
					

M - Machine
G - Grind

Supplementary Symbols

c. To supplement weld symbols that may call for more than one type of weld on a joint or groove, combined symbols are used to indicate combined welds.

Combined Welds

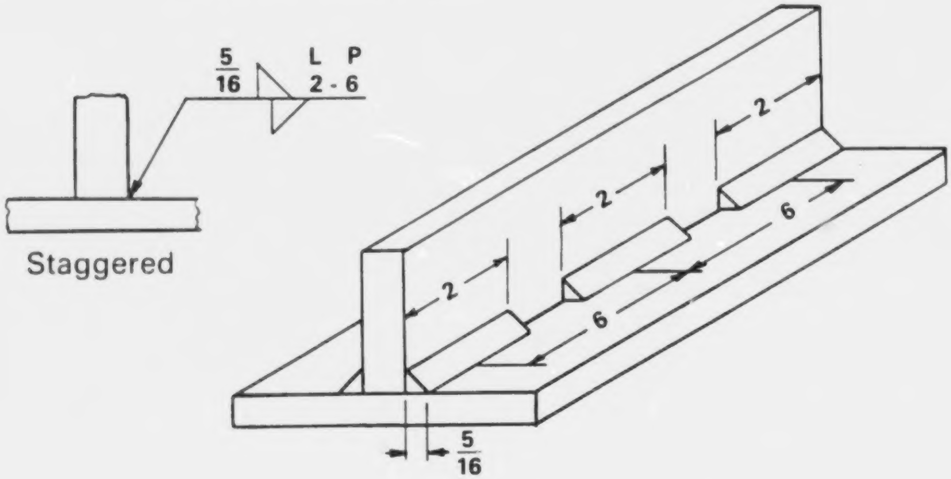


Information Sheet

40. Guidelines for dimensioning welds

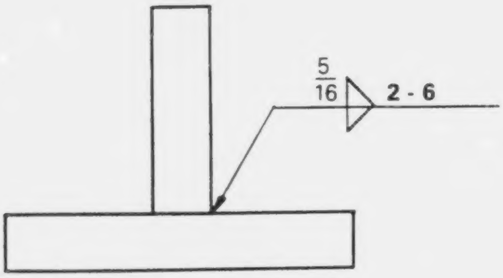
a. Dimensioning staggered weld calls for an indication of weld type, weld size, length of weld, and length of pitch, the on center distance between staggered welds.

Example: In the following illustrations, the weld size is 5/16″, the length of the wels is 2″ with a 6″ pitch.



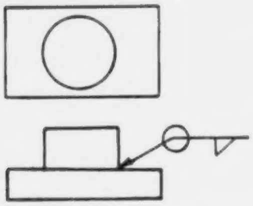
Staggered

b. Near side - opposite side dimensioning calls for weld size, symbol, length of weld, and pitch to all be on the reference line.

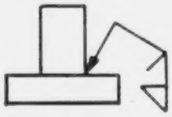


Near Side - Opposite Side

c. The weld all around symbol should be placed at the point where the reference line and arrow line intersect, and the combination weld should show a dual reference line.



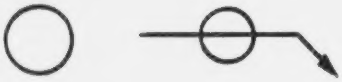
Weld All Around



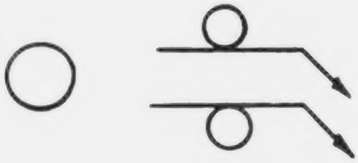
Combination Weld

41. Resistance welding symbols

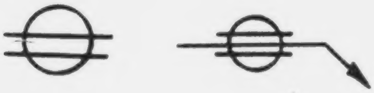
a. The symbol for a resistance spot weld is a circle with the reference line passing through its center.



b. The symbol for a projection weld is a circle that is placed above or below the reference line, depending on the side to be spot welded.

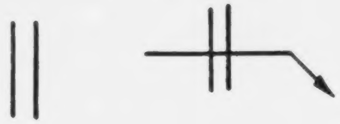


c. The symbol for a resistance seam weld is a circle crossed by a parallel line at the upper and lower quarters, and the reference line runs through its center.



Information Sheet

d. The symbol for a flash or upset weld is two perpendicular, parallel lines that cross the reference line at 90 degree angles.



42. Considerations for using adhesive for bonding materials

a. Before bonding adhesives are specified for use, they must first be determined functional for the structural demands, and for holding and sealing.

b. Chemical considerations also figure into the selection of adhesives; they must be considered for thermosetting or thermoplastic qualities, and for repetitive structure in reaction to epoxies, polyamides, polyurathanes, and polyacrylates.

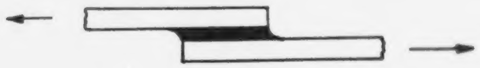
c. Adhesive application methods must also be considered, whether the material will be applied with solvent, with a hot melt, or in two parts.

d. Another consideration for using adhesives should be the nature of the property; the application may be metal to metal, metal to plastic, or plastic to glass.

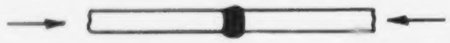
43. Considerations for joint design when using adhesive bonding

a. Consider the basic stress to which the joint will be subjected; select adhesive amount, and application technique as recommended.

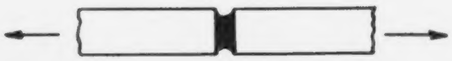
b. Types of stress to which bonded joints are subject to include: shear, tension, compression, cleavage, and peel.



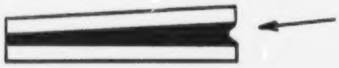
Shear



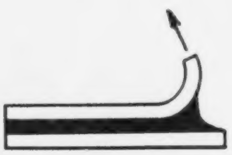
Compression



Tension



Cleavage

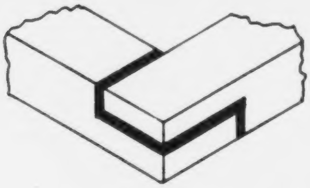


Peel

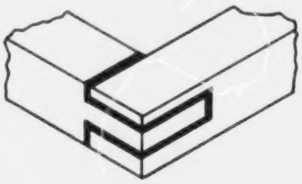
c. Remember a basic rule about joint design and adhesives: use as large a contact area as possible to assure maximum strength.

44. Joint designs for adhesive bonding

a. Some joint designs for adhesive bonding utilize traditional joints from carpentry and furniture making, the end lap joint and the mortise and tenon joint.

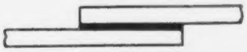


End Lap Joint

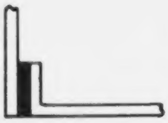


Mortise and Tenon

b. The lap joint and corner joint are other traditional joining configurations.

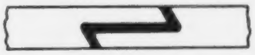


Lap Joint

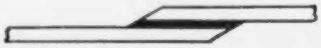


Corner Joint

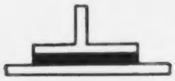
c. Other adhesive bonding joint designs include the joggle lap, the double butt lap, the tapered lap, and the T section stiffener.



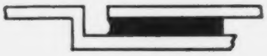
Double Butt Lap



Tapered Lap



T Section Stiffener



Joggle Lap

Information Sheet

45. CAD symbol libraries and their uses

a. 2D CAD symbol libraries are used to create top or side views for everything from bolts to fasteners.

Examples: Bolts, simplified, schematic or detailed threads; holes, countersunk, counterbore, pockets, and slots; round and square springs; all types of washers, nuts, fasteners, and weld symbols

b. 3D CAD symbol libraries are used to create features such as pockets, slots, and holes, and for other applications.

Examples: Bolts, screws, nuts, springs, washers, and miscellaneous fasteners

Fasteners and Hardware
Unit 5

Assignment Sheet 1—Construct Thread Symbols

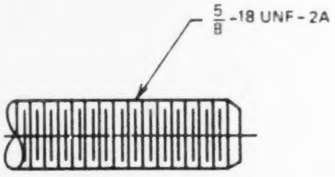
Name ______________________________ Overall Rating __________

Evaluation criteria	Rating
Appropriate scale use	_____
Thread symbol use	_____
Sumbol and letter use	_____
Note entries	_____

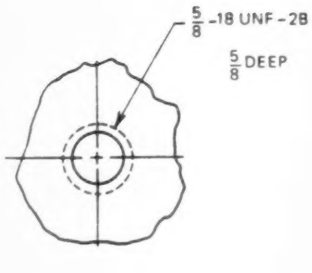
Directions: Using the screw thread tables included with this assignment sheet, draw on B size vellum or other media to a full or proper scale the thread symbols indicated in the problems that follow. Use the correct type of symbol, and letter the correct thread note as shown in the example.

> **CAD Alert:** Select 2D or 3D third-party software for fasteners and standard hardware. Enter the proper dimensions, and your CAD system will automatically draw the symbols.

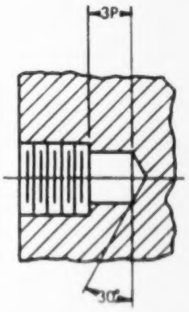
Example:



Schematic



Circular View



Section

Assignment Sheet 1

Problems:

A. Simplified external thread M 10 x 1.5 - 6gA

B. Simplified internal thread M 10 x 1.5 - 6HB thru 3/4 - 10NC - 2LH - 1.00 deep

C. Simplified external thread 3/4 - 10NC - 2LH

D. Simplified internal thread 3/4 - 10 NC - 2LH - 1.00 deep

E. Schematic external thread M3 x .5C - A

F. Schematic internal thread M3 x .5C - B

G. Schematic external thread 1/4 - 20 UNC - 2A

H. Schematic internal thread 1/4 - 20 UNC - 2B thru

Assignment Sheet 1

American National Standard Unified and American National Thread Screws

Nominal Diameter	Coarse[1] NC UNC		Fine[2] NF UNF		Extra Fine[4] NEF UNEF	
	Thds. per Inch	Tap Drill[5]	Thds. per Inch	Rap Drill[5]	Thds. per Inch	Tap Drill[5]
0 (.060)			80	3/64		
1 (.073)	64	No. 53	72	No. 53		
2 (.086)	56	No. 50	64	No. 50		
3 (.099)	48	No. 47	56	No. 45		
4 (.112)	40	No. 43	48	No. 42		
5 (.125)	40	No. 38	44	No. 37		
6 (.138)	32	No. 36	40	No. 33		
8 (.164)	32	No. 29	36	No. 29		
10 (.190)	24	No. 25	32	No. 21		
12 (.216)	24	No. 16	28	No. 14	32	No. 13
1/4	20	No. 7	28	No. 3	32	7/32
5/16	18	F	24	I	32	9/32
3/8	16	5/16	24	Q	32	11/32
7/16	14	U	20	25/64	28	13/32
1/2	13	27/64	20	29/64	28	15/32
9/16	12	31/64	18	33/64	24	33/64
5/8	11	17/32	18	37/64	24	37/64
11/16					24	41/64
3/4	10	21/32	16	11/16	20	45/64
13/16					20	49/64
7/8	9	49/64	14	13/16	20	53/64
15/16					20	57/64
1	8	7/8	12	59/64	20	61/64
1 1/16					18	1
1 1/8	7	63/64	12	1 3/64	18	1 5/64
1 3/16					18	1 9/64
1 1/4	7	17/64	12	1 11/64	18	1 3/16
1 5/16					18	1 17/64
1 3/8	6	17/32	12	1 19/64	18	1 5/16
1 7/16					18	1 3/8
1 1/2	6	1 11/32	12	1 27/64	18	1 7/16
1 9/16					18	1 1/2
1 5/8					18	1 9/16
1 11/16					18	1 5/8
1 3/4	5	1 9/16				
2	4 1/2	1 25/32				
2 1/4	4 1/2	2 1/32				
2 1/2	4	2 1/4				
2 3/4	4	2 1/2				
3	4	2 3/4				
3 1/4	4					
3 1/2	4					
3 3/4	4					
4	4					

Nominal Diameter	8-Pitch[3] Series 8N and 8UN		12-Pitch[3] Series 12N and 12UN		16-Pitch[3] Series 16N and 16UN	
	Thds. per Inch	Tap Drill[5]	Thds. per inch	Tap Drill[5]	Thds. per Inch	Tap Drill[5]
1/2			12	27/64		
9/16			12	31/64		
5/8			12	35/64		
11/16			12	39/64		
3/4			12	43/64	16	11/16
13/16			12	47/64	16	3/4
7/8			12	51/64	16	13/16
5/16			12	55/64	16	7/8
1	8	7/8	12	59/64	16	15/16
1 1/16			12	63/64	16	1
1 1/8	8	1	12	1 3/64	16	1 1/16
1 3/16			12	1 7/64	16	1 1/8
1 1/4	8	1 1/8	12	1 11/64	16	1 3/16
1 5/16			12	1 15/64	16	1 1/4
1 3/8	8	1 1/4	12	1 19/64	16	1 5/16
1 7/16			12	1 23/64	16	1 3/8
1 1/2	8	1 3/8	12	1 27/64	16	1 7/16
1 9/16					16	1 1/2
1 5/8	8	1 1/2	12	1 35/64	16	1 9/16
1 11/16					16	1 5/8
1 3/4	8	1 5/8	12	1 43/64	16	1 11/16
1 13/16					16	1 3/4
1 7/8	8	1 3/4	12	1 51/64	16	1 13/16
1 15/16					16	1 7/8
2	8	1 7/8	12.	1 59/64	16	1 15/16
2 1/16					16	2
2 1/8			12	2 3/64	16	2 1/16
2 3/16					16	2 1/8
2 1/4	8	2 1/8	12	2 11/64	16	2 3/16
2 5/16					16	2 1/4
2 3/8			12	2 19/64	16	2 5/16
2 7/16					16	2 3/8
2 1/2	8	2 3/8	12	2 27/64	16	2 7/16
2 5/8			12	2 35/64	16	2 9/16
2 3/4	8	2 5/8	12	2 43/64	16	2 11/16
2 7/8			12		16	
3	8	2 7/8	12		16	
3 1/8			12		16	
3 1/4	8		12		16	
3 3/8			12		16	
3 1/2	8		12		16	
3 5/8			12		16	
3 3/4	8		12		16	
3 7/8			12		16	
4	8		12		16	
4 1/4	8				16	
4 1/2	8				16	
4 3/4	8				16	
5	8				16	
5 1/4	8				16	

[1] ANSI B1.1
[2] Classes 1A, 2A, 3A, 1B, 2B, 3B, 2 and 3
[3] Classes 2A, 3A, 2B, 3B, 2 and 3
[4] Classes 2A, 2B, 2 and 3
[5] For approximate 75% full depth of thread

Assignment Sheet 1

Metric Screw Threads

Coarse general purpose		Fine	
Nominal Size & Thd Pitch	Tap Drill Diameter, mm	Nominal Size & Thd Pitch	Tap Drill Diameter, mm
M1.6 X 0.35	1.25		
M1.8 X 0.35	1.45		
*M2 X 0.4	1.6		
M2.2 X 0.45	1.75		
*M2.5 X 0.45	2.05		
*M3 X 0.5	2.50		
*M3 X 0.6	2.90		
*M4 X 0.7	3.30		
M4.5 X 0.75	3.75		
*M5 X 0.8	4.20		
*M6.3 X 1	5.30		
M7 X 1	6.00		
*M8 X 1.25	6.80	*M8 X 1	7.00
M9 X 1.25	7.75		
*M10 X 1.5	8.50	*M10 X 1.25	8.75
M11 X 1.5	9.50		
*M12 X 1.75	10.30	*M12 X 1.25	10.50
*M14 X 2	12.00	*M14 X 1.5	12.50
*M16 X 2	14.00	*M16 X 1.5	14.50
M18 X 2.5	15.50	M18 X 1.5	16.50
*M20 X 2.5	17.50	*M20 X 1.5	18.50
M22 X 2.5	19.50	M22 X 1.5	20.50
*M24 X 3	21.00	*M24 X 2	22.00
M27 X 3	24.00	M27 X 2	25.00
*M30 X 3.5	26.50	*M30 X 2	28.00
M33 X 3.5	29.50	M30 X 2	31.00
*M36 X 4	32.00	*M36 X 3	33.00
M39 X 4	35.00	M39 X 3	36.00
*M42 X 4.5	37.50	*M42 X 3	39.00
M45 X 4.5	40.50	M45 X 3	42.00
*M48 X 5	43.00	*M48 X 3	45.00
M52 X 5	47.00	M52 X 3	49.00
*M56 X 5.5	50.50	*M56 X 4	52.00
M60 X 5.5	54.50	M60 X 4	56.00
*M64 X 6	58.00	*M64 X 4	60.00
M68 X 6	62.00	M68 X 4	64.00
*M72 X 6	66.00		
*M80 X 6	74.00		
*M90 X 6	84.00		
*M100 X 6	94.00		

Metric Fasteners Standards IFI 5000 (1976)

*Preferred sizes for commercial threads and fasteners

Fasteners and Hardware
Unit 5

Assignment Sheet 2—Construct Symbols of Bolts, Screws, and Nuts

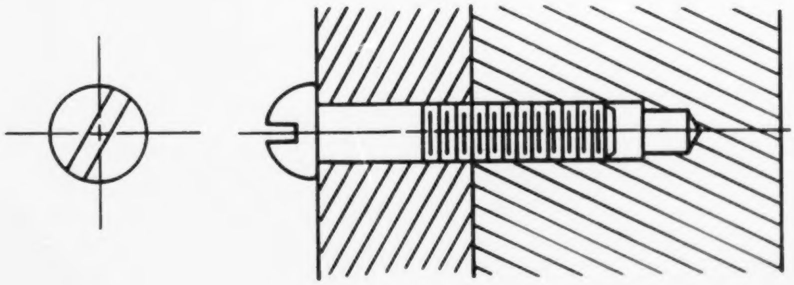
Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Appropriate scale use	______
Thread symbol use	______
Symbol and letter use	______
Neatness and appearance	______

Directions: Using bolt, screw, and nut tables, draw on B size vellum or other media to a full or proper scale, the fasteners indicated in the following problems. Draw each fastener so that it is shown holding parts together. Letter correct description abbreviated below each symbol as shown in the following example.

CAD Alert: Select third-party software for bolts and nuts. Enter the correct data, and your CAD system will automatically generate the drawings.

Example:



Assignment Sheet 2

Problems:

Note: All tap drill sizes should be specified for external.

A. M 6.3 x 1 - 40mm long hexagon head cap screw

B. 3/4 x 2 1/2 hexagon head cap screw

C. 5/8 - 11UNC - 2B square nut

D. M 6.3 x 1 hexagon nut

E. 3/4 - 10UNC -2A 2 1/2 long hexagon cap screw

F. No. 10 (.1900) - 32NF - 3, 5/8 long fillister head machine screw

G. M 8 x 1.25, 30mm long slotted pan head machine screws

H. 3/8 - 16UNC - 2A, 3/4 long square head flat point set screw

I. M 10 x 1.5 12mm long hexagon socket head set screw full dog point

J. #204 woodruff key

Fasteners and Hardware
Unit 5

Assignment Sheet 3—Construct an Assembly Containing Various Fasteners

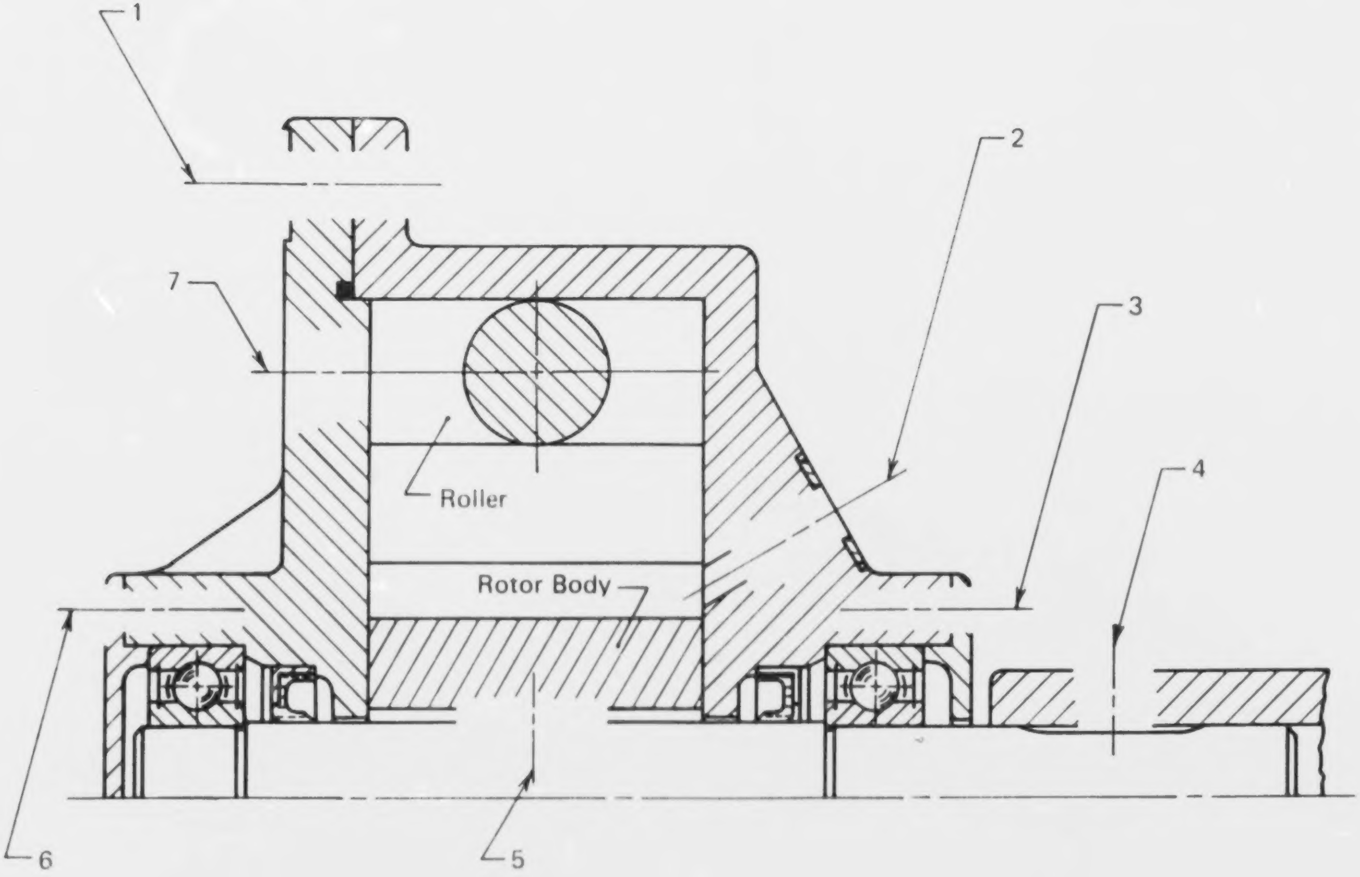
Name ______________________ Overall Rating __________

Evaluation criteria	**Rating**
Fastener descriptions from parts list	______
Section assemblies completed	______
Symbol and letter use	______
Neatness and appearance	______

Directions: Using fastener tables, draw on B size vellum or other media an assembly drawing with fasteners listed in the problems. Letter correct fastener descriptions in parts list directly above title block. Complete the sectioned assembly as specified by your instructor.

1. 3/8 x 1" hexagon cap screw and American Standard regular lockwasher
2. 3/8 x 1/2 slotted pan head machine screw and special washer
3. No. 10 x 1/2 slotted round head machine screw
4. 3/8 x 1/2 slotted headless cup point set screw
5. #606 Woodruff key
6. #10 x 1/2 slotted oval head machine screw
7. 3/4 pipe tap

Assignment Sheet 3


1
2
3
4
5
6
7
Roller
Rotor Body

HYDRAULIC PUMP

Fasteners and Hardware
Unit 5

Assignment Sheet 4—Construct a Weldment Assembly Drawing

Name ______________________________ Overall Rating __________

Evaluation criteria	Rating
Use of welding symbols	______
Complete dimensioning of assembly	______
Neatness and appearance	______

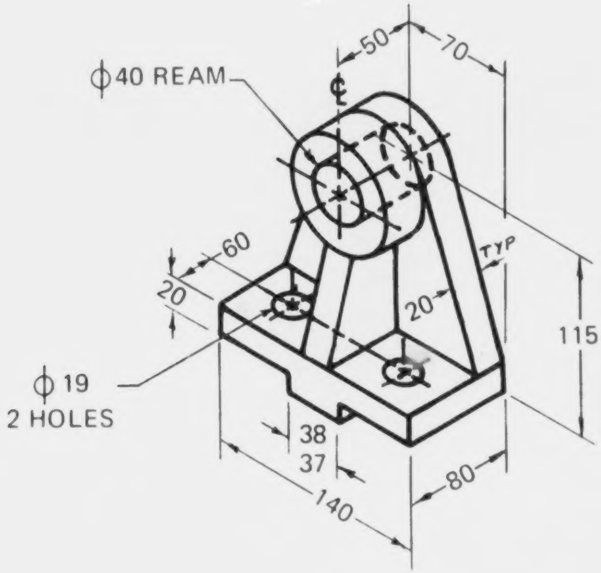
Directions: From the following problems, select A or B, and draw on B size vellum or other media a weldment assembly. Use proper welding symbols as shown in a previous objective, and be sure to dimension the assembly completely.

CAD Alert: Select third-party software for welding symbols. Use the symbols and other available library aids to quickly generate your weldment assembly drawing with CAD.

Problems:

A. Bracket—Metric

Scale 1:10



Fasteners and Hardware
Unit 5

Assignment Sheet 5—Construct Spring Drawings to Include Specifications

Name ______________________ Overall Rating __________

Evaluation criteria	**Rating**
Compression spring construction and specifications	______
Extension spring construction and specifications	______
Torsion spring construction and specifications	______
Neatness and appearance	______

Directions: On A size vellum or other media, construct spring drawings to include the specifications as listed with each of the following problems.

> **CAD Alert:** Select third-party software for spring drawings. Apply the symbols and other library aids to quickly generate your spring drawings and specifications.

Problems:

A. Detail drawing representation of a compressed spring with the following specifications:

   1. 2″ free length
   2. 10 gage diameter of wire
   3. 3/4″ OD
   4. 1/4 pitch

B. Schematic drawing of an extension spring with the following specifications:

   1. 3″ length
   2. 2 1/2″ free length
   3. 5/8″ OD
   4. 1/4 pitch

Assignment Sheet 5

C. Schematic drawing of a torsion spring with the following specifications:

1. 4″ length
2. 15 coils
3. 1/8″ OD
4. Length of ends 1 1/4″
5. Angle 50°

Fasteners and Hardware
Unit 5

Assignment Sheet 6—Construct Keys in Assembled Positions

Name ______________________ Overall Rating __________

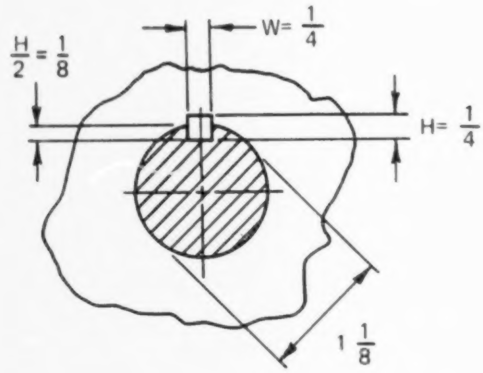
Evaluation criteria	**Rating**
Detail of shaft and key	______
Use of dimensions	______
Tile and scale presentation	______
Neatness and appearance	______

Directions: Using the tables included with this assignment sheet, construct keys for the problems given. Draw to given scale on A size vellum and letter title and scale under each detail.

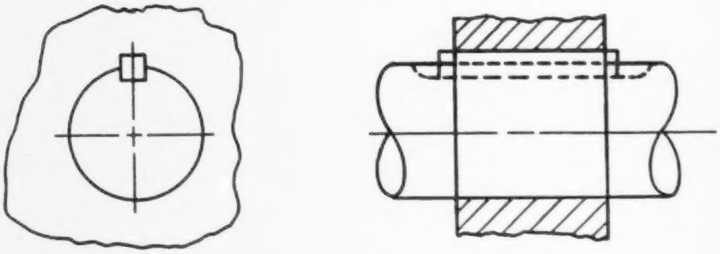
Example: Construct an assembled detailed drawing of a 1 1/8" shaft square keyed to a wheel. Only show detail of the key, shaft, and wheel.

1. Using Table 6-C, find shaft diameter range for 1 1/8" shaft
2. Answer is 15/16" to 1 1/4"
3. Reading across the line, square stock key says W = 1/4 and H - 1/4
4. Draw detail based on dimensions in illustration

Assignment Sheet 6



DRAWING INFORMATION



DRAWING

Problems:

A. Construct an assembled detailed drawing of a 1 1/2" diameter shaft square keyed to a wheel. Only show detail of the key, shaft, and wheel. Draw in 1/2" = 1" scale in the upper left quarter of the "A" size vellum. Letter title and scale under detail.

B. Construct an assembled detailed drawing of a 4 3/4" diameter shaft flat keyed to a wheel. Only show detail of the key, shaft, and wheel. Draw in 1/4" = 1' scale in the upper right quarter of the "A" size vellum. Letter title and scale under detail.

C. Construct an assembled detailed drawing of a 9/16" diameter shaft Woodruff keyed to a pulley. Only show detail of the key, shaft, and pulley. Draw in 2 X scale in the lower left quarter of the "A" size vellum. Letter title and scale under detail.

Note: Table 6-A will locate the Woodruff key size and Table 6-B will give the drawing details.

D. Construct an assembled detailed drawing of a 1 3/4" diameter shaft Woodruff keyed to a hub. Only show detail of the key, hub, and shaft. Draw in full size in the lower right quarter of the "A" size vellum. Letter title and scale under detail.

Assignment Sheet 6

Woodruff Keys[1]—American national Standard

Key No.[2]	Nominal Sizes				Maximum Sizes		
	A X B	E	F	G	H	D	C
204	1/16 X 1/2	3/64	1/32	5/64	.194	.1718	.203
304	3/32 X 1/2	3/64	3/64	3/32	.194	.1561	.203
305	3/32 X 5/8	1/16	3/64	7/64	.240	.2031	.250
404	1/8 X 1/2	3/64	1/16	7/64	.194	.1405	.203
405	1/8 X 5/8	1/16	1/16	1/8	.240	.1875	.250
406	1/8 X 3/4	1/16	1/16	1/8	.303	.2505	.313
505	5/32 X 5/8	1/16	5/64	9/64	.240	.1719	.250
506	5/32 X 3/4	1/16	5/64	9/64	.303	.2349	.313
507	5/32 X 7/8	1/16	5/64	9/64	.365	.2969	.375
606	3/16 X 3/4	1/16	3/32	5/32	.303	.2193	.313
607	3/16 X 7/8	1/16	3/32	5/32	.365	.2813	.375
608	3/16 X 1	1/16	3/32	5/32	.428	.3443	.438
609	3/16 X 1 1/8	5/64	3/32	11/64	.475	.3903	.484
807	1/4 X 7/8	1/16	1/8	3/16	.365	.2500	.375
808	1/4 X 1	1/16	1/8	3/16	.428	.3130	.438
809	1/4 X 1 1/8	5/64	1/8	13/64	.475	.3590	.484
810	1/10 X 1 1/4	5/64	1/8	13/64	.537	.4220	.547
811	1/4 X 1 3/8	3/32	1/8	7/32	.584	.4690	.594
812	1/4 X 1 1/2	7/64	1/8	15/64	.631	.5160	.641
1008	5/16 X 1	1/16	5/32	7/32	.428	.2818	.438
1009	5/16 X 1 1/8	5/64	5/32	15/64	.475	.3278	.484
1010	5/16 X 1 1/4	5/64	5/32	15/64	.537	.3908	.547
1011	5/16 X 1 3/8	3/32	5/32	8/32	.584	.4378	.594
1012	5/16 X 1 1/2	7/64	5/32	17/64	.631	.4848	.641
1210	3/8 X 1 1/4	8/64	3/16	17/64	.537	.3595	.547
1211	3/8 X 1 3/8	3/32	3/16	9/32	.584	.4065	.594
1212	3/8 X 1 1/2	7/64	3/16	19/64	.631	.4335	.641

[1] ANSI B17.2-1967, R1972

[2] Key numbers indicate nominal key dimensions. The last two digits give the nominal diameter B in eights of an inch, and the digits before the last two give the nominal width A in thirty-seconds of an inch.

Assignment Sheet 6

Woodruff Key Sizes for Different Shaft Diameters[1]

Shaft Diameter	5/16 to 3/8	7/15 to 1/2	9/16 to 3/4	13/16 to 15/16	1 to 1 3/16	1 1/4 to 1 7/16	1 1/2 to 1 3/4	1 13/16 to 2 1/8	2 3/16 to 2 1/2
Key Numbers	204	304 305	404 405 406	505 506 507	606 607 608 609	807 808 809	810 811 812	1011 1012	1211 1212

[1] Suggested sizes; not standard.

TABLE 6-C

Keys—Square, Flat, Plain Taper[1], and Gib Head

Shaft Diameters	Square Stock Key	Flat Stock Key	Gib Head Taper Stock Key					
			Square			Flat		
			Height	Length	Height to Chamfer	Height	Length	Height to Chamfer
D	W = H	W X H	C	F	E	C	F	E
1/2 to 9/16	1/8	1/8 X 3/32	1/4	7/32	5/32	3/16	1/8	1/8
5/8 to 7/8	3/16	3/16 X 1/8	5/16	9/32	7/32	1/4	3/16	5/32
15/16 to 1 1/4	1/4	1/4 X 3/16	7/16	11/32	11/32	5/16	1/4	3/16
1 5/16 to 1 3/8	5/16	5/16 X 1/4	9/16	13/32	13/32	3/8	5/16	1/4
1 7/16 to 1 3/4	3/8	3/8 X 1/4	11/16	15/32	15/32	7/16	3/8	5/16
1 13/16 to 2 1/4	1/2	1/2 X 3/8	7/8	19/32	5/8	5/8	1/2	7/16
2 5/16 to 2 /34	5/8	5/8 X 7/16	1 1/16	23/32	3/4	3/4	5/8	1/2
2 7/8 to 3 1/4	3/4	3/4 X 1/2	1 1/4	7/8	7/8	7/8	3/4	5/8
3 3/8 to 3 3/4	7/8	7/8 X 5/8	1 1/2	1	1	1 1/16	7/8	3/4
3 7/8 to 4 1/2	1	1 X 3/4	1 3/4	1 3/16	1 3/16	1 1/4	1	13/16
4 3/4 to 5 1/2	1 1/4	1 1/4 X	2	1 7/16	7/16	1 1/2	1 1/4	1
5 3/4 to 6	1 1/2	7/8	2 1/2	1 3/4	1 3/4	1 3/4	1 1/2	1 1/4
		1 1/2 X 1						

[1] Plain taper square and flat keys have the same dimensions as the plain parallel stock keys, with the addition of the taper on top. Gib head taper square and flat keys have the same dimensions as the plain taper keys, with the addition of the gib head.

Stock lengths for plain taper and gib head taper keys: The minimum stock length equals 4W, and the maximum equals 16W. The increments of increase of length equal 2W.

Fasteners and Hardware
Unit 5

Assignment Sheet 7—Write Specifications for Hardware from Vendor Catalogs

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Number of vendor catalogs used	______
Number of problems completed	______
Completeness of specifications	______
Neatness and appearance	______

Directions: Use vendor hardware catalogs such as *The Thomas Register* to find the hardware for each of the following problems. Select a specific type or size for each problem. Write a specification to include vendor's name and address, cost, material, and specifications such as size, length, type, etc. for each item selected. Letter answer on A size vellum converting the sheet to a parts list to include part number, description to include vendor's name, address, and specification, and cost and material.

> **CAD Alert:** It is relatively expensive, but the *Thomas Register* is available on CD ROM and you can use your CAD workstation to speed search by manufacturer's name, by hardware item, or even search by entering key words.

Problems:

A. Compression spring

B. Tension spring

C. Woodruff key

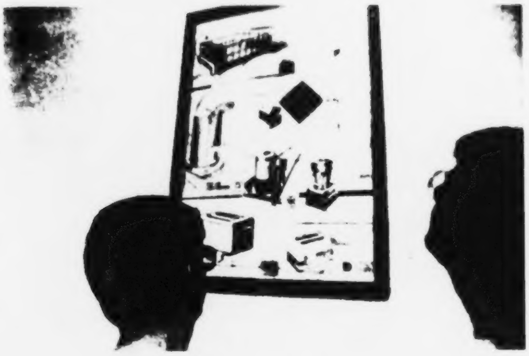
D. Internal tooth washer

E. Dart-type spring clip

F. Spring washer to control end pressure

G. Hook lock fastener—quick operating

H. Weld nut



Presentation Drawings
Unit 6

Objective Sheet

Unit Objective

After completing this unit, the student should be able to shade pictorials, construct conceptual presentation sketches, construct design sketches, construct dimetric and oblique presentation drawings, construct a two-point perspective, and construct an exploded assembly presentation drawing. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to presentation drawings with their correct definitions.
2. Match types of presentation sketches and drawings with their purposes.
3. Arrange in order the steps in sketching.
4. Complete statements about guidelines for ellipse construction.
5. Complete statements about places where presentation drawings are used.
6. Select true statements about techniques for shading presentation drawings.
7. Match types of axonometric drawings with their characteristics.
8. Match types of oblique drawings with their characteristics.
9. Match parts of an exploded assembly drawing with their uses.
10. Complete statements about CAD applications for presentation drawings.
11. Select true statements about special requirements for patent drawings.

Objective Sheet

12. Shade pictorials. (Assignment Sheet 1)
13. Construct conceptual presentation sketches. (Assignment Sheet 2)
14. Construct design sketches. (Assignment Sheet 3)
15. Construct a dimetric presentation drawing. (Assignment Sheet 4)
16. Construct an oblique presentation drawing. (Assignment Sheet 5)
17. Construct a two-point perspective presentation drawing. (Assignment Sheet 6)
18. Construct an exploded assembly presentation drawing. (Assignment Sheet 7)

Presentation Drawings
Unit 6

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for enrichment of exceptional students as well as accommodation of special needs students.
4. Make transparencies from the transparency masters included with this unit. These appear in the teacher edition only and are designed to be used with the following objectives:

   TM 1—Reduction Ratios (Objective 1)
   TM 2—Catalog Presentation Drawing (Objective 5)
   TM 3—Sales Literature Presentation Drawing (Objective 5)
   TM 4—Technical Report Presentation Drawings (Objective 5)
   TM 5—Exploded Assembly Drawing (Objective 9)
   TM 6—Exploded Assembly Drawing (Continued) (Objective 9)
   TM 7—Patent Drawing (Objective 10)

5. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.
6. Develop teaching plan. Adjust for different learning styles.
7. Make copies of Unit Evaluation Form.

Delivery and Application

8. Provide students with unit of instruction.
9. Discuss unit and specific objectives.
10. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
11. Discuss the assignment and job sheets. Review criteria for evaluation of these activities.

Suggested Activities

Evaluation

12. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

13. Make copies of the written test. Add or modify test items as needed.

14. Give written test.

15. Compile assignment sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignments.

16. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Have a proportional scale handy to use for demonstration as you teach the terms and definitions in Objective 1. Skill areas: **Foundation skills, math**.

2. Review the assignment sheets carefully and make alternate assignments as you see fit. Items in Assignment Sheet 1 are referenced in several other job sheets. You may wish to assign items from Assignment Sheet 1 so students will have a variety of sketches, drawings, and perspectives to examine by the time they complete this unit. Skill areas: **Foundation skills, science, and math**.

3. Have catalogs and parts books and other literature available to demonstrate some of the items mentioned in Objective 5. Have several exploded views available and show how these are referenced to parts lists. Skill areas: **Foundation skills, reading**.

Resources Used in Developing This Unit

1. Bertoline, Gary R. *Fundamentals of CAD*, 2nd Ed. Albany, NY: Delmar Publishing, Inc., 1988.

2. Giesecke, Frederick E. *Technical Drawing*, 9th Ed. New York: Macmillan Publishing Company, 1991.

3. Goetsch, David L. *Microcadd Computer-Aided Design and Drafting on Microcomputers*. New Jersey: Prentice Hall, 1988.

Suggested Activities

4. Jensen, Cecil, et. al. *Computer-Aided Engineering Drawing Using AutoCAD*. New York: Glencoe/McGraw-Hill, 1990.

Suggested Supplemental Resources

1. *Guide for Patent Draftsmen*. Washington, DC: U.S. Department of Commerce, Patent and Trademark Office.

   Note: The *Guide* can be purchased from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

2. Hoelscher, R. P., et. al. *Industrial Production Illustration*. New York: McGraw-Hill Book Co., 1946.

   Note: This book is out of print and difficult to find, but it's worth looking for because it has excellent examples and illustrations.

Presentation Drawings
Unit 6

Answers to Assignment Sheets

Assignment Sheet 1

Evaluated according to drawing selected and evaluation criteria written in the assignment sheet.

Assignment Sheet 2

Evaluated according to design selected and evaluation criteria written in the assignment sheet.

Assignment Sheet 3

Evaluated according to design sketch attempted and evaluation criteria written in the assignment sheet.

Assignment Sheet 4

Evaluated according to diametric drawing selected and evaluation criteria written in the assignment sheet.

Assignment Sheet 5

Evaluated according to oblique drawing selected and evaluation criteria written in the assignment sheet.

Assignment Sheet 6

Evaluated according to the two point perspective selected and evaluation criteria written in the assignment sheet.

Assignment Sheet 7

Evaluated according to object selected for an exploded assembly and evaluation criteria written in the assignment sheet.

Presentation Drawings
Unit 6

Answers to Written Test

1. a. 9
   b. 6
   c. 1
   d. 5
   e. 11
   f. 3
   g. 8
   h. 2
   i. 10
   j. 12
   k. 7
   l. 4

2. a. 3
   b. 1
   c. 3

3. a. 2
   b. 1
   c. 3

4. a. 60°
   b. Diameter
   c. Perpendicular

5. a. Catalogs
   b. Clarity
   c. Sales literature

6. a, b

7. a. 2
   b. 3
   c. 1

8. a. 3
   b. 1
   c. 2

9. a. 5
   b. 7
   c. 8
   d. 3
   e. 2
   f. 9
   g. 4
   h. 1
   i. 6

10. a. Wire frame
    b. Intensity

11. a, c, e, f, g

Presentation Drawings
Unit 6

Written Test

Name ______________________ Date ________________ Score ____________

1. Match the terms on the right with their correct definitions. Definitions are continued on the following page.

_____ a. Simple exterior embellishments utilizing light effects to enhance the pictorial qualities of an object

_____ b. Sketch, mechanical drawing, or rendering designed to illustrate a technical subject and help sell or clarify its idea to a client

_____ c. Freehand drawing of technical ideas without instruments

_____ d. Carefully drawn sketches prepared to be given to someone else to make detail drawings

_____ e. Drawing showing all parts in relationship with each other and how they fit together

_____ f. Recording and communicating technical ideas that are in the process of development

_____ g. Three dimensional drawing in axonometric, oblique, or perspective to imitate a picture of an object

_____ h. A simplified drafting technique to reduce drafting time that combines photographs and line drawing on a standard sheet layout

_____ i. A simplified drafting technique in which drawing segements are pasted or typed in position on a drawing form and photographically reproduced

1. Freehand technical sketching
2. Photodrafting
3. Conceptual sketches
4. Reduction ratios
5. Design sketches
6. Presentation sketch or drawing
7. Airbrushing
8. Pictorial drawing
9. Shading
10. Paste-up drafting
11. Exploded assembly drawing
12. Patent drafting

Written Test

_______j. Drawing an invention in pictorial and explanatory form to convey the correct interpretation

_______k. A method of touching up photographs and adding shading to line drawings by blowing ink or paint pigments through an air cap onto the drawing

_______l. To reduce a drawing proportionally using a ratio

2. Match types of presentation sketches and drawings with their purposes. Place the number of the sketch or drawing type in the blank beside its description.

_______a.	A drafter with an idea that solves a problem or defines a new product would make several of these.	1. Design
		2. Presentation
_______b.	A drafter selects the best of a previous type and uses it as a guide to make another type which is complete with dimensions.	3. Conceptual
_______c.	A drafter who wants to show a design to a client who may not understand technical drawings should make an easy-to-understand one of these.	

3. Arrange in order the steps in sketching. Place a 1 beside the first step, then complete the steps in order.

_______a. Block the object in proportionately with light construction lines.

_______b. Use light construction lines to sketch an enclosing box or cylinder in correct proportions.

_______c. Clean up unnecessary construction lines with an eraser, and darken the final visible lines.

Written Test

4. Complete statements about guidelines for ellipse construction. Circle the material that best completes each of the following statements.

   a. The ellipse on the top or horizontal plane has the major axis horizontal, and the ellipse on the left and right side planes has its major axis (**60°**) (**90°**) from the horizontal.

   b. Box in the (**arc**) (**diameter**) of the circle and sketch in the ellipse.

   c. Draw the (**horizontal**) (**perpendicular**) bisector on each side of the box with a straight edge; use a compass to construct circles at the intersections of the bisectors and from the corners to give an approrpiate ellipse.

5. Complete statements about places where presentation drawings are used. Circle the material that best completes each of the following statements.

   a. Presentation drawings are in great demand for (**magazines**) (**catalogs**) and parts books.

   b. Presentation drawings add (**sex appeal**) (**clarity**) to technical reports and patent applications.

   c. Presentation drawings give a boost to (**advertising**) (**manufacturing drawings**) and assist sales people with client proposals.

6. Select true statements about techniques for shading presentation drawings. Place an "X" beside each true statement.

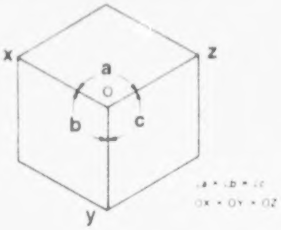
   _____a. Line shading is a common drawing technique as is stippling, or the use of dots.

   _____b. Smudge shading is another technique as are press-on materials from transfer sheets.

   _____c. Other techniques include air brushing and the use of crayons.

7. Match types of axonometric drawings with their characteristics. Place the number of the drawing type in the blank beside its illustration. Illustrations continued on next page.

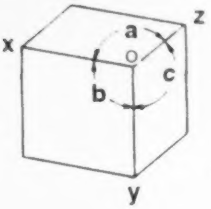
   _____a.



1. Trimetric
2. Isometric
3. Dimetric

Written Test

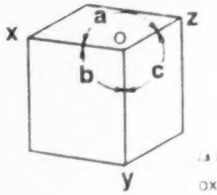
_______b.



∠a = ∠c

OX = OY

_______c.

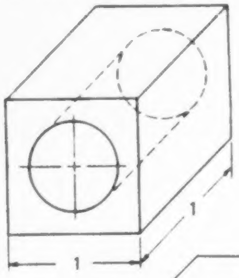


∠s a, b, and c are unequal

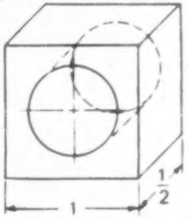
OX, OY, and OZ are unequal

8. Match types of oblique drawings with their characteristics. Place the number of the drawing type in the blank beside its illustration.

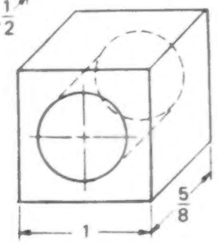
_______a.



_______b.



_______c.



1. Cabinet
2. General
3. Cavalier

Written Test

9. Match parts of an exploded assembly drawing with their uses. Place the number of the part in the blank beside the description of its use.

_______a. Used if they reference a part list

_______b. Used to tie number to objects

_______c. Used if immediate identification is important

_______d. Indicate where parts fit

_______e. Used to differentiate one part from another

_______f. Can be duplicated and pasted onto a drawing to save time

_______g. Should be in a natural position rather than just fitted on the paper

_______h. Should be on same sheet as the drawing, directly above the title

_______i. Line in front take precedence over lines in back by gapping back lines for front lines

1. Parts list
2. Shading
3. Flow lines
4. Axis
5. Numbers
6. Overlapping parts
7. Leaders
8. Part names
9. Standard hardware

10. Complete statements about CAD applications for presentation drawings. Circle the material that best completes each of the following statements.

a. Wire frame CAD drawings (**cannot**) (**can**) quickly be made into presentation drawings.

b. CAD presentation drawings permit quick change of surface texture, and a quick change of light direction and light (**color**) (**intensity**).

Written Test

11. Select true statements about special requirements for patent drawings. Place an "X" beside each true statement.

_______a. Draw mechanically correct so patent reviewers will clearly understand the invention.

_______b. Do dimension and detail as you would a working drawing.

_______c. Illustrate each item or object the patent claims.

_______d. Add center lines and notes.

_______e. Draw in india ink or equivalent.

_______f. Use heavy, smooth white paper, 8 1/2 by 14" or 21.0 by 29.7cm: two ply or three ply bristol board is preferred.

_______g. Line shade and surface shade to improve legibility.

*Permission to duplicate this test is granted.

Presentation Drawings
Unit 6

Unit Evaluation Form

Student Name ______________________ Unit Rating ________

Assignment Sheet 1—Shade Pictorials Rating ______

Comments: ______________________

____

Assignment Sheet 2—Construct Conceptual Presentation Sketches Rating ______

Comments: ______________________

____

Assignment Sheet 3—Construct Design Sketches Rating ______

Comments: ______________________

____

Assignment Sheet 4—Construct a Dimetric Presentation Drawing Rating ______

Comments: ______________________

____

Assignment Sheet 5—Construct an Oblique Presentation Drawing Rating ______

Comments: ______________________

____

Assignment Sheet 6—Construct a Two-Point Perspective Presentation Drawing Rating ______

Comments: ______________________

____

Unit Evaluation Form

Assignment Sheet 7—Construct an Exploded Assembly Presentation Drawing Rating ______

Comments: ____

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

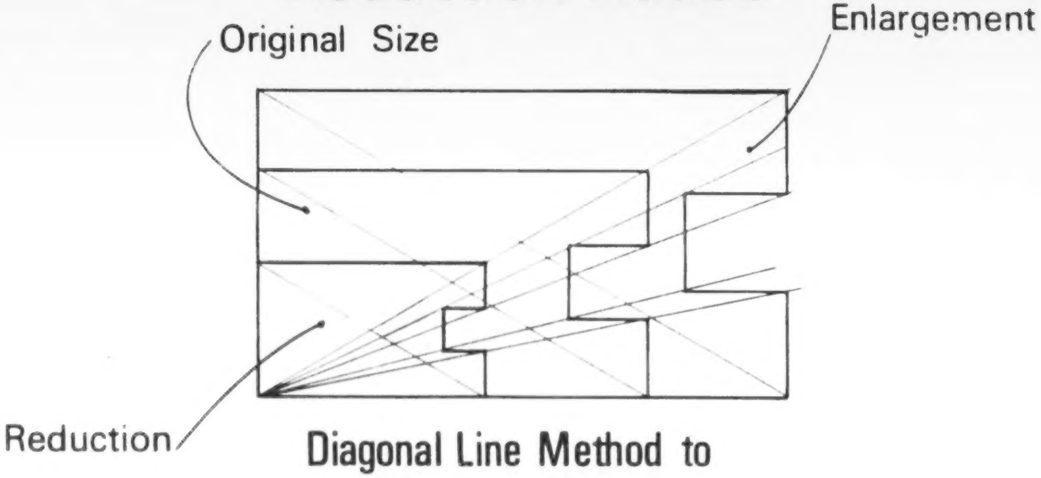
____

Teacher Signature ______________________ Date __________

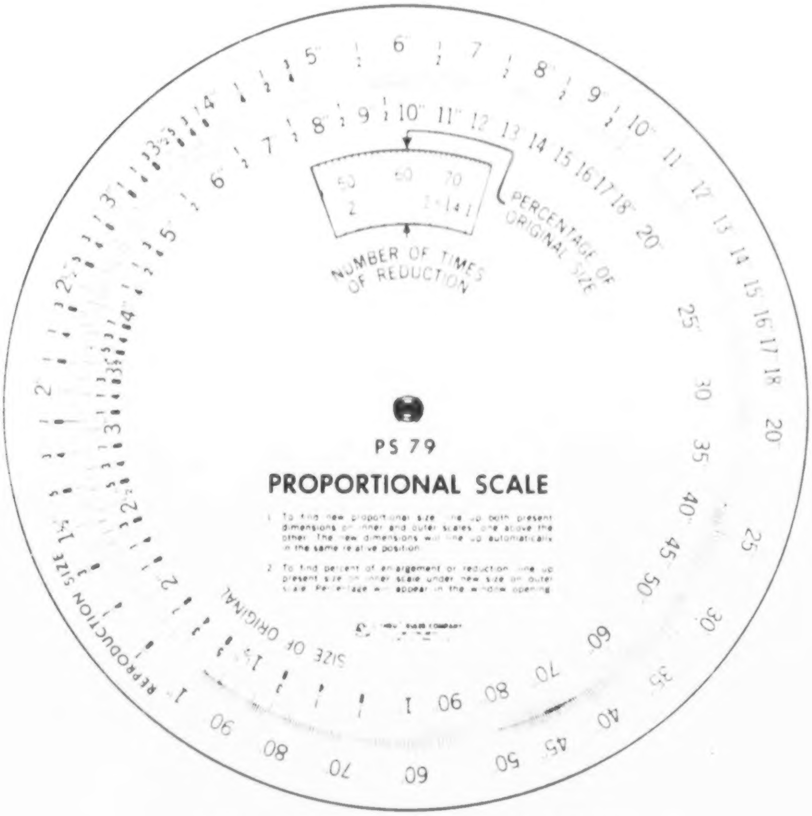
Student Signature ______________________ Date __________

*Permission to duplicate this form is granted.

Reduction Ratios

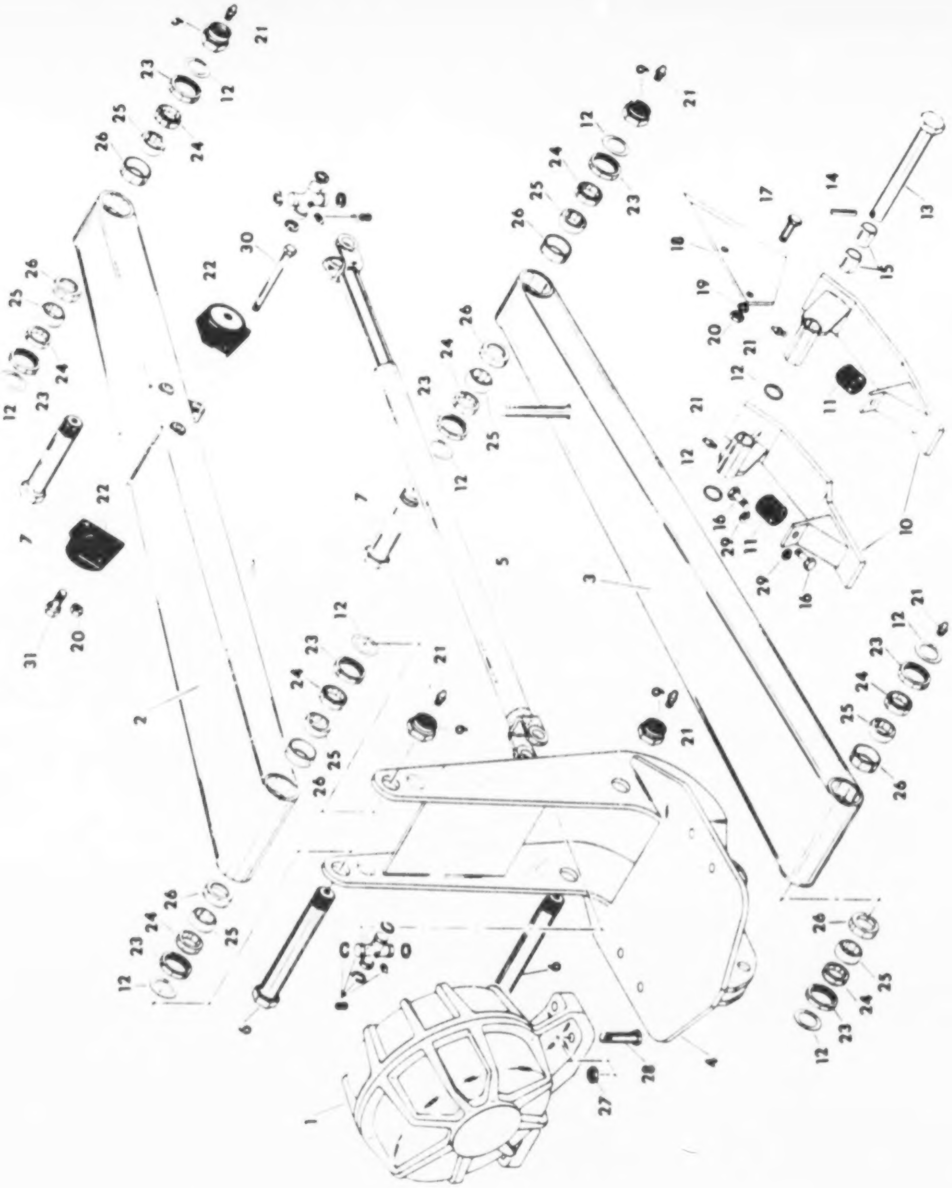

Original Size
Enlargement
Reduction

Diagonal Line Method to Enlarge or Reduce


PS 79
PROPORTIONAL SCALE
NUMBER OF TIMES OF REDUCTION
PERCENTAGE OF ORIGINAL SIZE
SIZE OF ORIGINAL
REPRODUCTION SIZE

Circular Proportional Scale

Catalog Presentation Drawing


1
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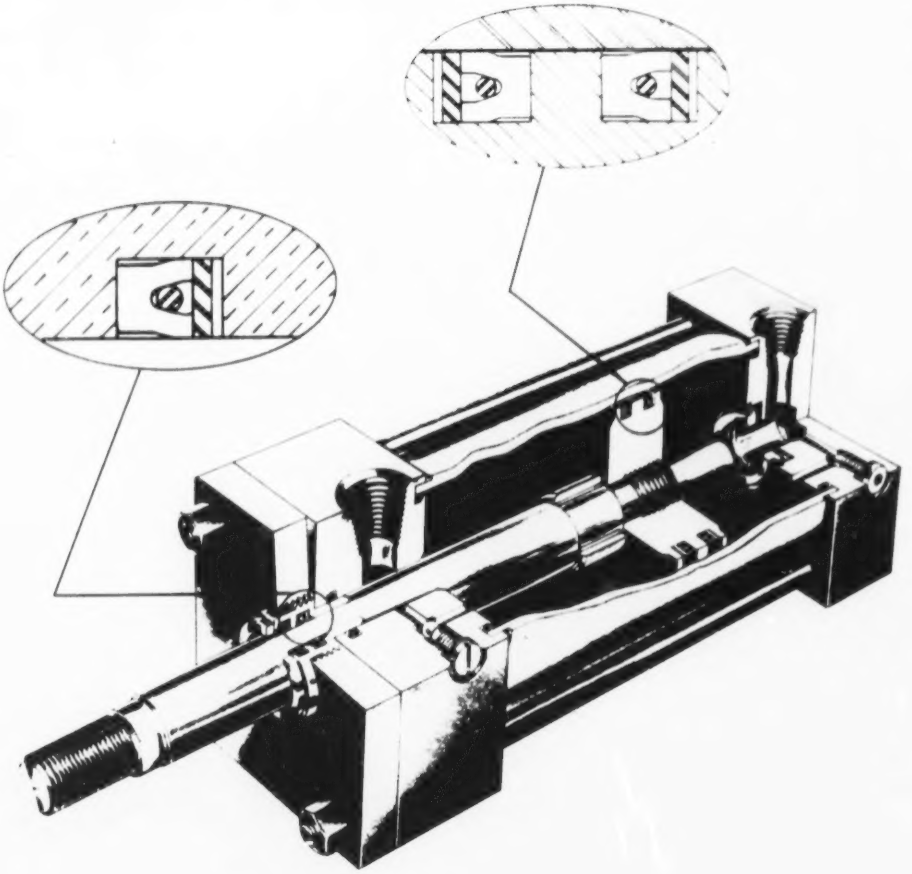
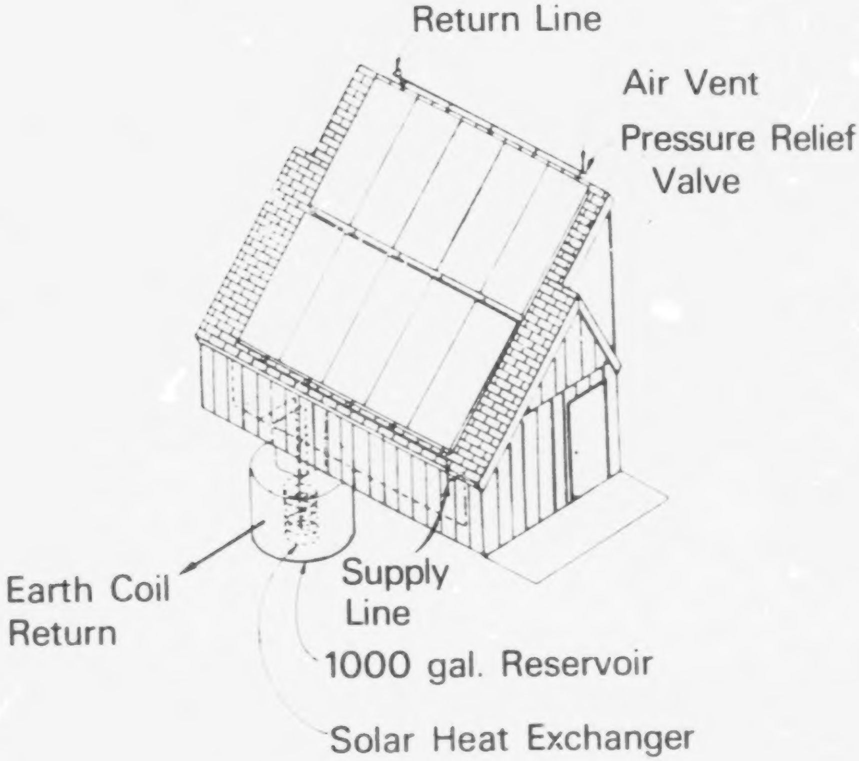
21
22
23
24
25
26
27
28
29
30
31

Courtesy of Charles Machine Works, Perry, Oklahoma

Sales Literature
Presentation Drawing



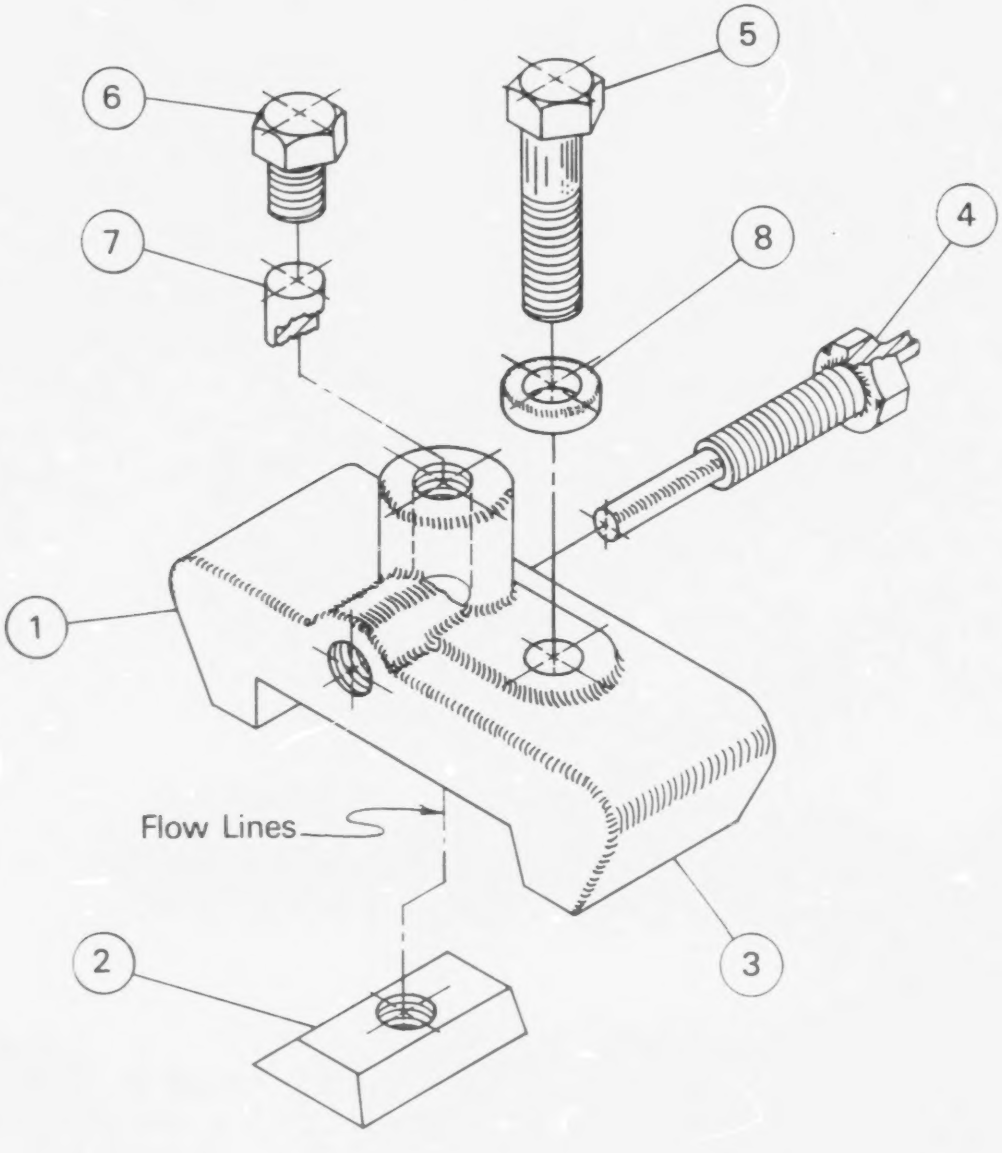
Technical Report Presentation Drawing


Return Line
Air Vent
Pressure Relief Valve
Earth Coil Return
Supply Line
1000 gal. Reservoir
Solar Heat Exchanger

Solar Hut and Earth Coil Reservoir

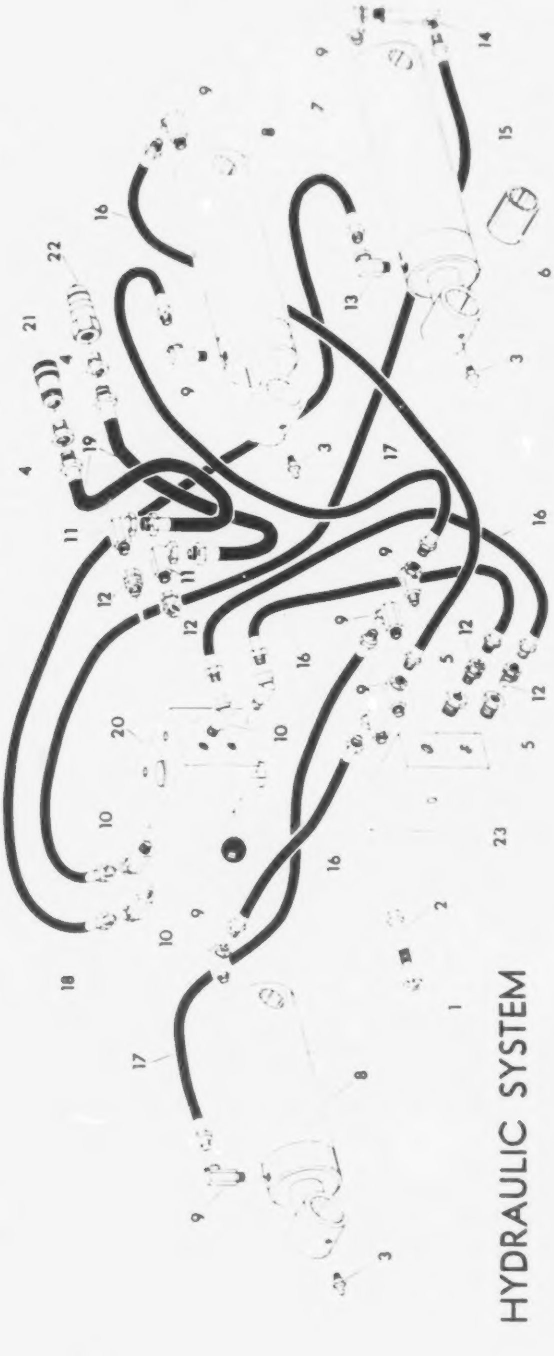
Courtesy of Dr. James Bose, Oklahoma State University

Exploded Assembly Drawing


5
6
7
8
4
1
Flow Lines
2
3

Exploded Assembly Drawing

(Continued)


HYDRAULIC SYSTEM
14
15
9
7
8
9
16
22
21
4
19
4
13
6
3
9
3
17
16
11
9
12
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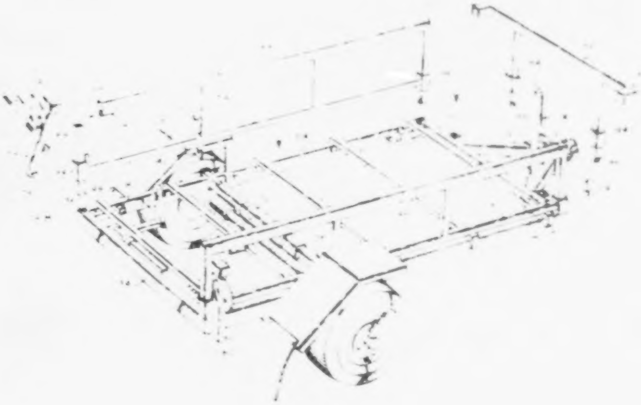
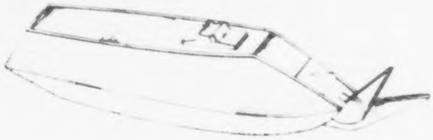
16
12
5
12
9
20
10
5
10
23
16
2
9
10
18
1
17
8
9
3

Patent Drawing

3.623.744
COLLAPSIBLE TRAILER APPARATUS
Melvin C. Bertness. Santa Cruz. and Arnold E. Lyle. Capitola. both of Calif.. assignors to Bermaco Enterprises. San Jose. Calif.
Filed Dec. 11. 1969. Ser. No. 884.240
Int. Cl. B62d *23 100*
U.S. Cl. 280—106 12 Claims



222.660
ELECTRIC SCISSORS
John K. Miles. Columbus. Ind.. and Jack F. Baker. Glenview. Ill.. assignors to Arvin Industries. Inc.. Columbus. Ind.
Filed Aug. 12. 1970. Ser. No. 24.433
Term of patent 14 years
Int. Cl. D8—*03*
U.S. Cl. D8—61



Presentation Drawings
Unit 6

Information Sheet

1. Terms and definitions

    a. **Airbrushing** — A method of touching up photographs and adding shading to line drawings by blowing ink or paint pigments through an air cap onto the drawing

    b. **Conceptual sketches** — Recording and communicating technical ideas that are in the process of development

    c. **Design sketches** — Carefully drawn sketches prepared to be given to someone else to make detail drawings

    d. **Exploded assembly drawing** — Drawing showing all parts in relationship with each other and how they fit together

    e. **Freehand technical sketching** — Freehand drawing of technical ideas without instruments

    f. **Paste-up drafting** — A simplified drafting technique in which drawing segments are pasted or typed in position on a drawing form and photographically reproduced

    g. **Patent drafting** — Drawing an invention in pictorial and explanatory form to convey the correct interpretation

    h. **Pictorial drawing** — Three dimensional drawing in axonometric, oblique, or perspective to imitate a picture of an object

    i. **Photodrafting** — A simplified drafting technique to reduce drafting time that combines photographs and line drawing on a standard sheet layout

    j. **Presentation sketch or drawing** — Sketch, mechanical drawing, or rendering designed to illustrate a technical subject and help sell or clarify its idea to a client

    k. **Reduction ratios** — To reduce a drawing proportionally using a ratio

    l. **Shading** — Simple exterior embellishments utilizing light effects to enhance the pictorial qualities of an object

Information Sheet

2. **Types of presentation sketches and drawings and their purposes**

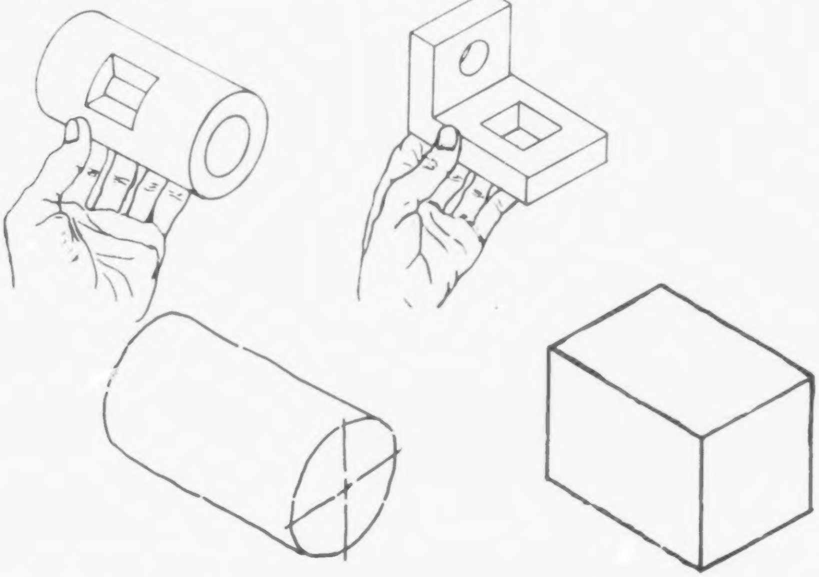
   a. **Conceptual** — A drafter with an idea that solves a problem or defines a new product would make several conceptual sketches of the idea.

   b. **Design** — A drafter selects the best conceptual sketch made and uses it as a guide to make a design sketch that is complete with dimensions.

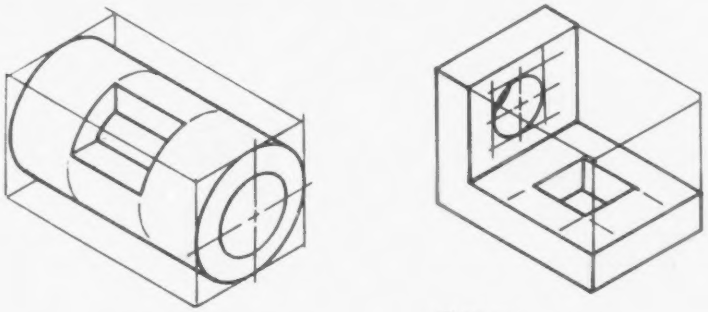
   c. **Presentation** — A drafter who wants to show a design to a client who may not understand technical drawings, should make an easy-to-understand presentation drawing.

3. **Steps in sketching**

   a. Use light construction lines to sketch an enclosing box or cylinder in correct proportions.

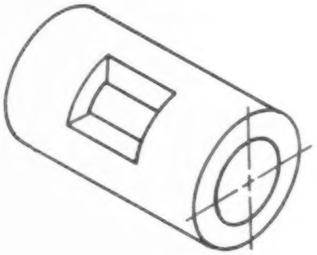


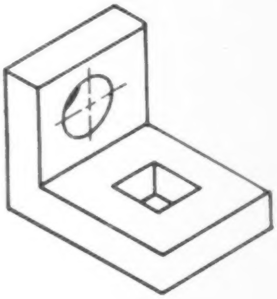
   b. Block the object in proportionately with light construction lines



Information Sheet

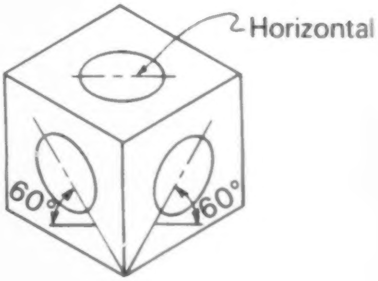
c. Clean up unnecessary construction lines with an eraser, and darken the final visible lines.



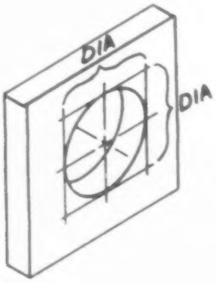


4. Guidelines for ellipse construction

a. The ellipse on the top or horizontal plane has the major axis horizontal, and the ellipse on the left and right side planes has its major axis 60° from the horizontal.

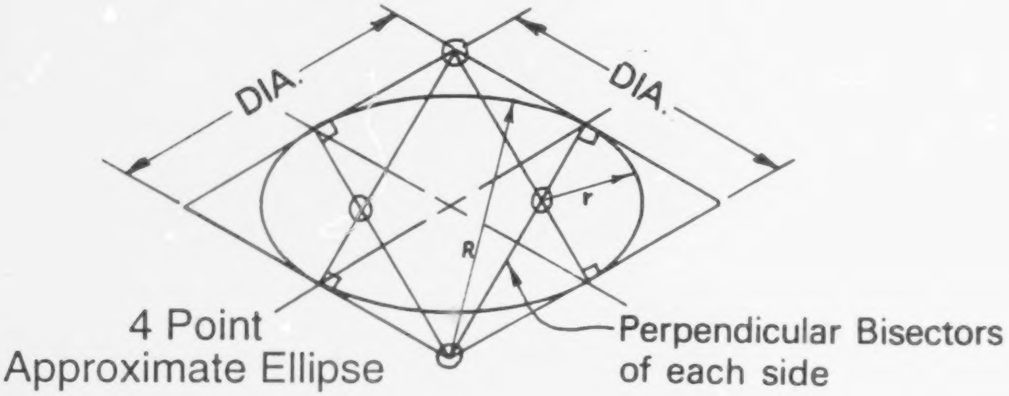


b. Box in the diameter of the circle and sketch in the ellipse.



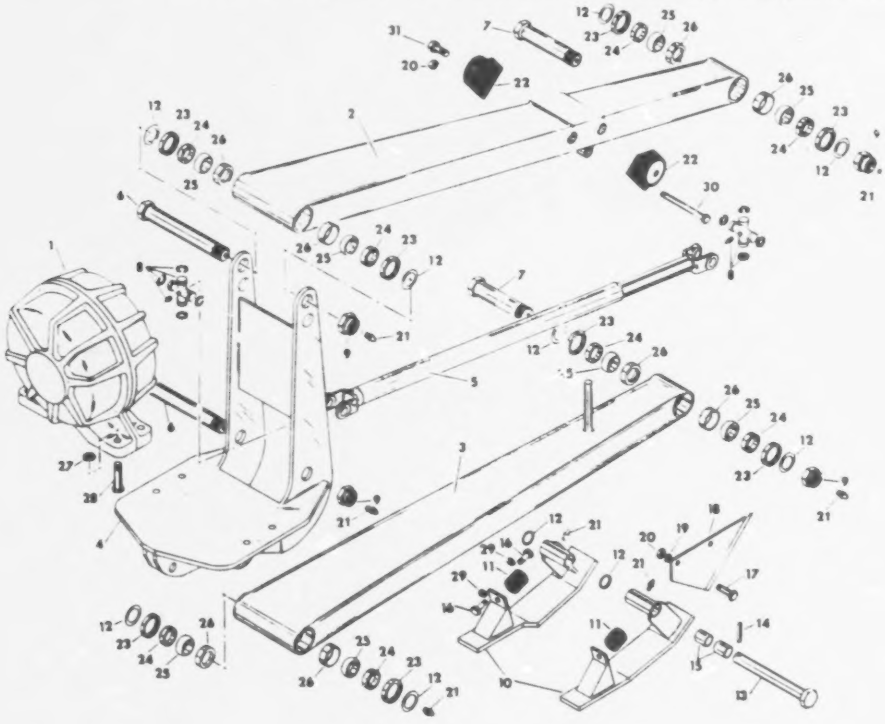
Information Sheet

c. Draw the perpendicular bisector on each side of the box with a straight edge; use a compass to construct circles at the intersections of the bisectors and from the corners to give an approximate ellipse.


DIA.
DIA.
r
R
4 Point Approximate Ellipse
Perpendicular Bisectors of each side

5. Places where presentation drawings are used

a. Presentation drawings are in great demand for catalogs and parts books.


31
20
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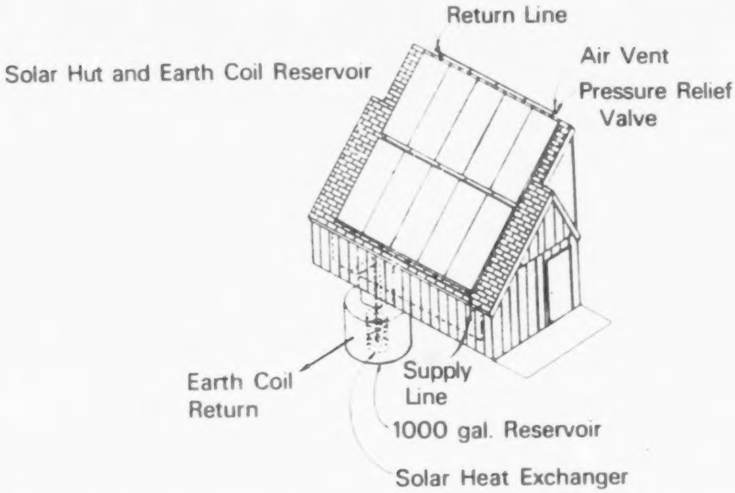
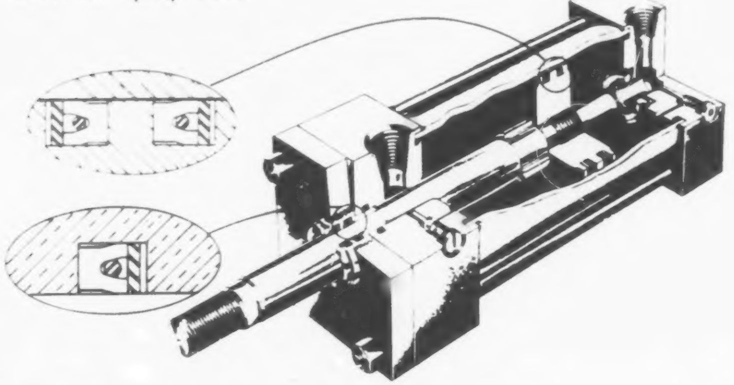
Information Sheet

b. Presentation drawings add clarity to technical reports and patent applications.

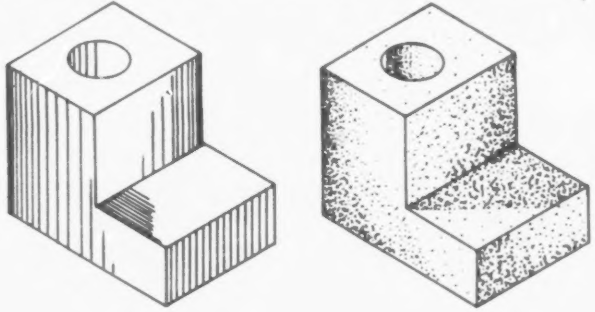

Return Line
Air Vent
Solar Hut and Earth Coil Reservoir
Pressure Relief Valve
Earth Coil Return
Supply Line
1000 gal. Reservoir
Solar Heat Exchanger

c. Presentation drawings give a boost to sales literature and assist sales people with client proposals.



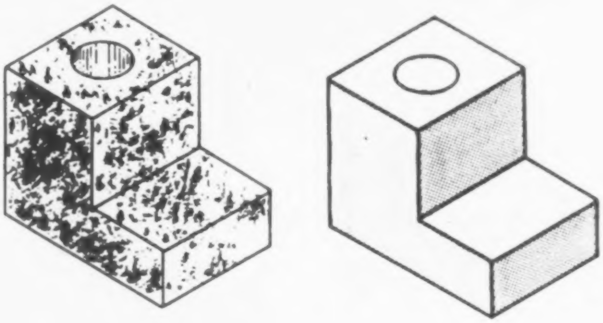
6. Techniques for shading presentation drawings

a. Line shading is a common drawing technique as is stippling, or the use of dots.

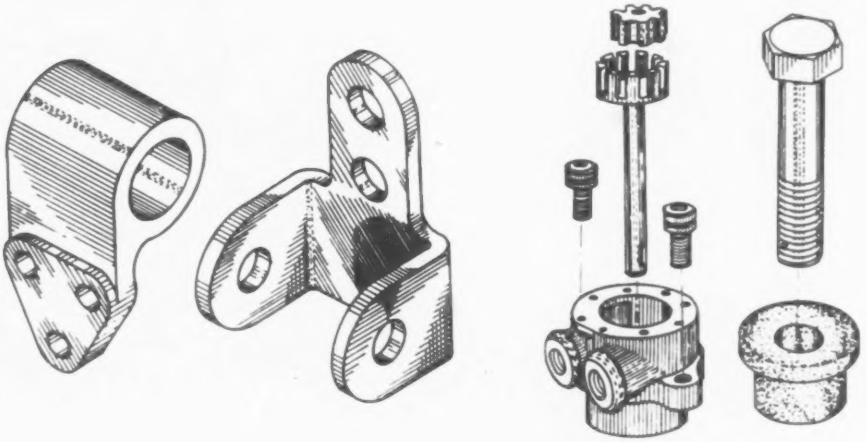


Information Sheet

b. Smudge shading is another technique as are press-on materials from transfer sheets.

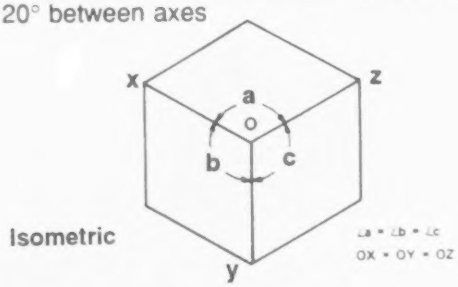


c. Other techniques include air brushing and using varieties of shading and shadowing.



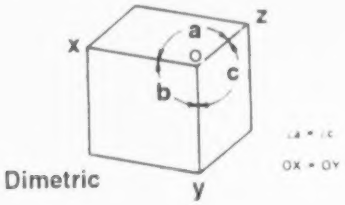
7. Types of axonometric drawings and their characteristics

a. **Isometric**—Has width, height, and depth on equal scale, all angles are equal, and there are 120° between axes

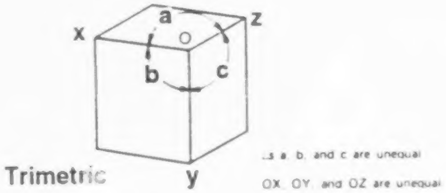


Information Sheet

b. **Dimetric**—Has width and height at full scale, two angles are equal, and two dimensions are equal

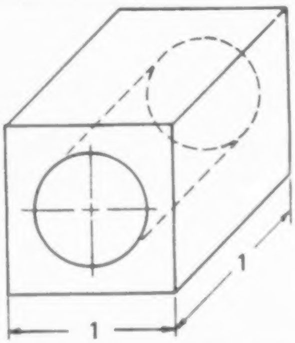

x
z
a
o
b
c
y
Dimetric
∠a = ∠c
OX = OY

c. **Trimetric**—Width, height, and depth are unequal, all axes are at different angles, and dimensions are unequal

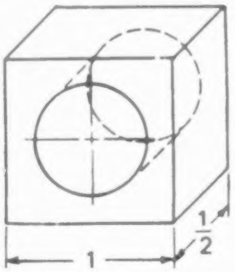

x
a
z
o
b
c
y
Trimetric
∠s a, b, and c are unequal
OX, OY, and OZ are unequal

8. Types of oblique drawings and their characteristics

a. **Cavalier**—An oblique drawing with true length on all axes

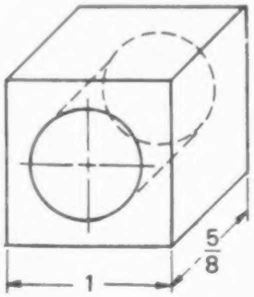


b. **Cabinet**—An oblique drawing with half scale on depth axis



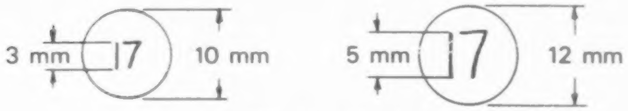
Information Sheet

c. **General**—An oblique drawing with depth axis at any scale



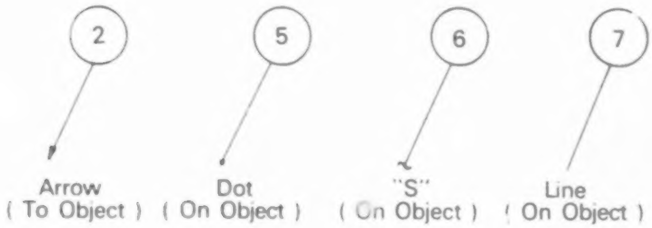
9. **Parts of an exploded assembly drawing and their uses**

a. **Numbers**—Used if they reference a parts list


3 mm
17
10 mm
5 mm
17
12 mm

Identification Numbers

b. **Leaders**—Used to tie number to objects


2
5
6
7
Arrow
(To Object)
Dot
(On Object)
"S"
(On Object)
Line
(On Object)

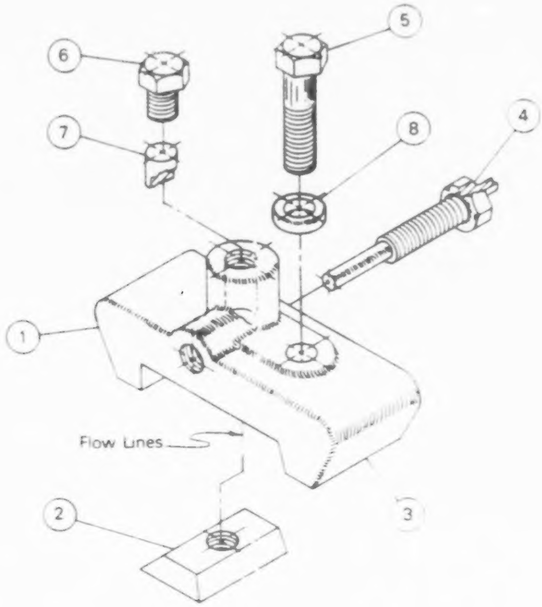
Leaders

c. **Part names**—Used if immediate identification is important

Note: Either number or part names may be used in an exploded view, but if numbers are used, there must be a corresponding parts list.

Information Sheet

d. **Flow lines**—Indicate where parts fit



e. **Shading**—Used to differentiate one part from another

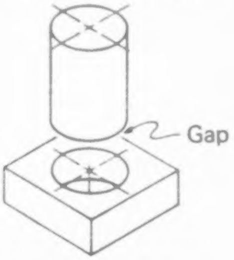
f. **Standard hardware**—Can be duplicated and pasted onto a drawing to save time

g. **Axis**—Should be in a natural position rather than just fitted on the paper

h. **Parts list (PL)**—Should be on same sheet as the drawing directly above the title block

i. **Overlapping parts**—Lines in front take precedence over lines in back by gapping back lines for front lines

Note: For best results, ink the drawing and reduce it for the final copy.



Overlapping Parts

Information Sheet

10. CAD applications for presentation drawings

a. Wire frame CAD drawings can quickly be made into presentation drawings.

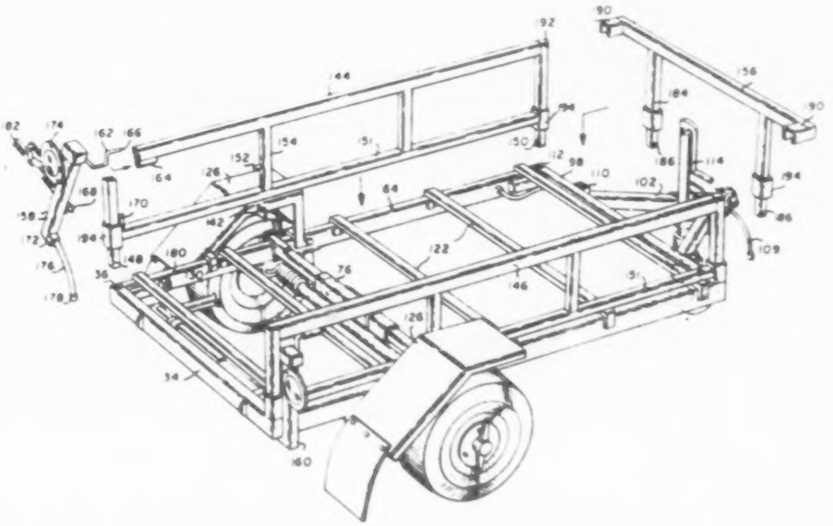
b. CAD presentation drawings permit quick change of surface texture, and a quick change of light direction and light intensity.

11. Special requirements for patent drawings

a. Draw mechanically correct so patent reviewers will clearly understand the invention.

b. Do not dimension or detail as you would a working drawing.

c. Illustrate each item or object the patent claims.



182
174
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34
160

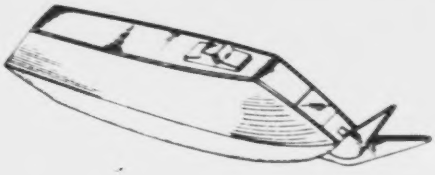
d. Omit center lines and notes.

e. Draw in india ink or equivalent.

f. Use heavy, smooth white paper, 8 1/2 by 14" (21.6 by 35.6cm) or 21.0 by 29.7cm (DIN size A4); two ply or three ply bristol board is preferred.

Information Sheet

g. Line shade and surface shade to improve legibility.



Presentation Drawings
Unit 6

Assignment Sheet 1—Shade Pictorials

Name ______________________ Overall Rating __________

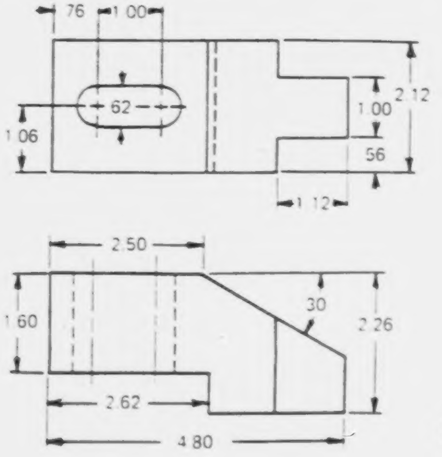
Evaluation criteria	Rating
Basic isometric construction	______
Print preparation	______
Number of shading techniques executed	______

Directions: On B size vellum or media selected by your instructor, construct an isometric drawing of one of the following problems. Use pencil or ink, and draw to appropriate scale. Make four quality blueline prints and then shade each print using a different shading technique. Shade the original drawing using the **best** shading technique you used on the prints, make a blueline of the print, and then turn in all your blueline prints to your instructor for evaluation.

CAD Alert: Use a CAD system to construct 3D wireframes of one or more of the problems, and delete hidden lines in the 3D view. Use the CAD system to shade your drawing.

Problems:

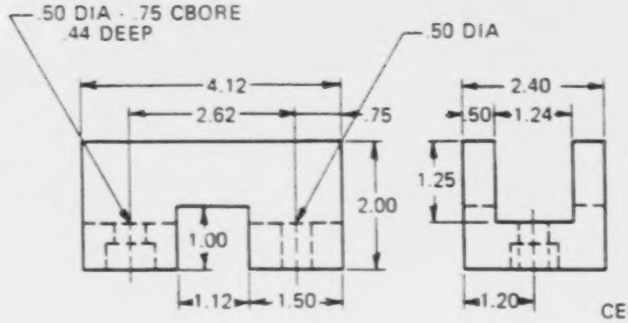
A.



LOCATOR

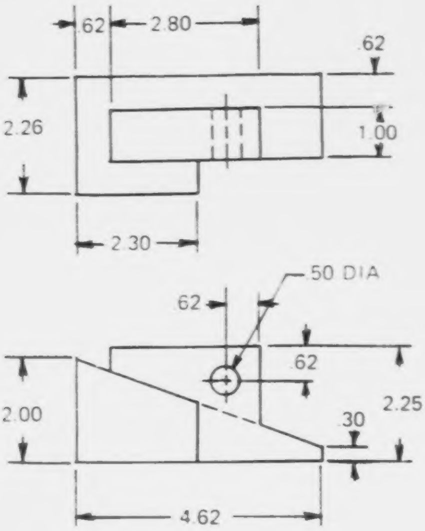
Assignment Sheet 1

B.


.50 DIA - .75 CBORE
.44 DEEP
.50 DIA
4.12
2.62
.75
2.00
1.00
1.12
1.50
2.40
.50
1.24
1.25
1.20

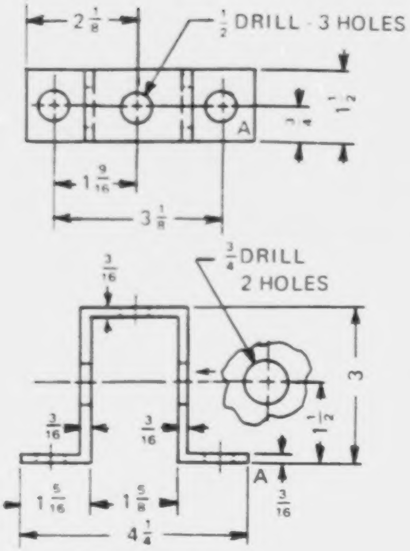
CENTER BRACKET

C.


.62
2.80
.62
2.26
1.00
2.30
.50 DIA
.62
.62
2.00
2.25
.30
4.62

SLIDE

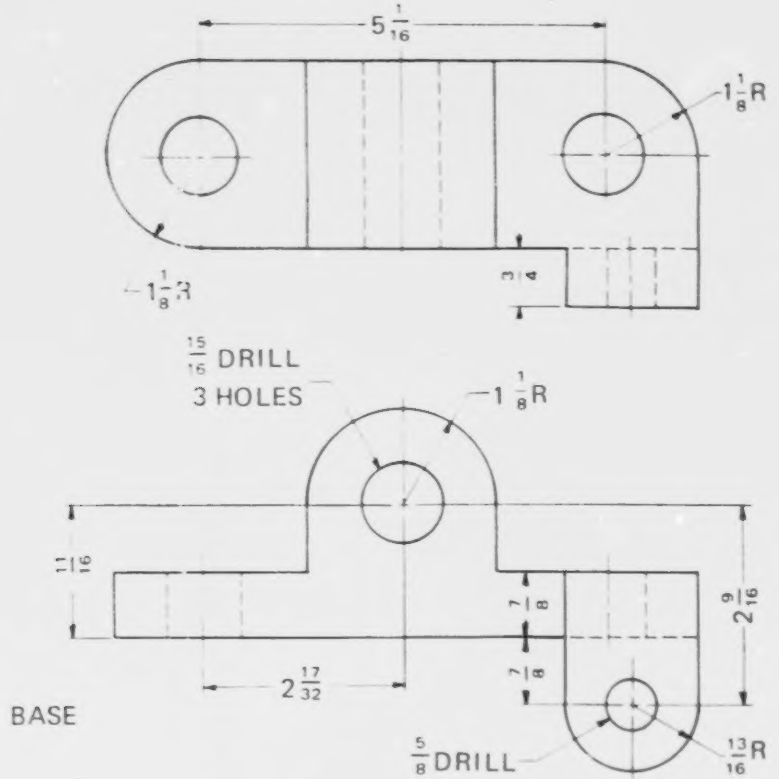
D.


2 1/8
1/2 DRILL - 3 HOLES
A
3/4
1 1/2
1 9/16
3 1/8
3/16
3/4 DRILL
2 HOLES
3
3/16
3/16
1 1/2
A
3/16
1 5/16
1 5/8
4 1/4

GEAR SUPPORT

Assignment Sheet 1

E.


5 1/16
1 1/8 R
1 1/8 R
3/4
15/16 DRILL
3 HOLES
1 1/8 R
11/16
7/8
7/8
2 9/16
2 17/32
BASE
5/8 DRILL
13/16 R

Presentation Drawings
Unit 6

Assignment Sheet 2—Construct Conceptual Presentation Sketches

Name ________________________ Overall Rating __________

Evaluation criteria	Rating
Basic conceptual sketch	______
Dimensions and notes	______
Parts ID and shape description	______

Directions: On A size vellum or media selected by your instructor, construct conceptual sketches of one of the following problems to include: 1—applicable dimensions and notes, 2—parts identification, and 3—shape description.

Problems:

A. Design safety or security devices for fire or theft to help save lives and prevent injury

B. Design a new or improved educational aid for your instructor

C. Design an improvement in vehicle transportation or racing

D. Design a home improvement product

Presentation Drawings
Unit 6

Assignment Sheet 3—Construct Design Sketches

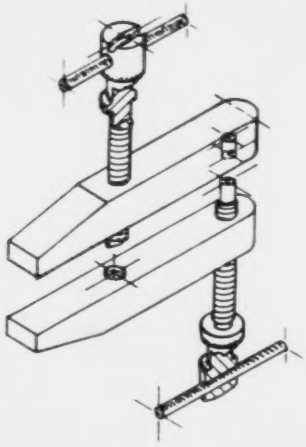
Name ________________________________ Overall Rating __________

Evaluation criteria	**Rating**
Shape description	______
Size dimensions and notes	______
Estimated material specifications	______

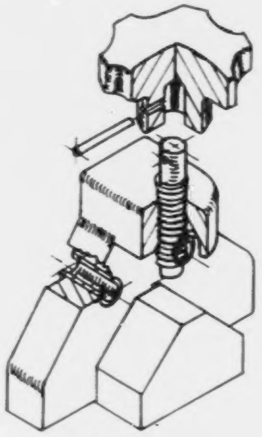
Directions: Using two sheets of A size vellum or media selected by your instructor, construct design sketches of two parts for one of the problems below or a problem from Assignment Sheet 2. Include the following: 1—shape description such as multiview and/or pictorial, 2—estimated size dimensions and notes, and 3—estimated material specifications.

Problems:

A.



B.



Presentation Drawings
Unit 6

Assignment Sheet 4—Construct a Dimetric Presentation Drawing

Name ______________________ Overall Rating __________

Evaluation criteria	**Rating**
Basic dimetric drawing	______
Blueline print shading	______
Original print shading	______

Directions: On B size vellum or media selected by your instructor, construct a dimetric drawing of one of the problems from Assignment Sheet 1. Use pencil or ink and draw to appropriate scale. You will need to select your own dimetric axis. Make two quality blueline prints, and shade each print with a **different** type of shading. Shade the original dimetric with your **best** shading, and turn in the blueline prints and the original to your instructor for evaluation.

CAD Alert: Use a CAD system to construct a 3D wireframe of a problem from Assignment Sheet 1, and rotate the problem in space to a dimetric position. Delete hidden lines in the dimetric, and use the CAD system to shade.

Presentation Drawings
Unit 6

Assignment Sheet 5—Construct an Oblique Presentation Drawing

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Basic oblique drawing	______
Blueline print shading	______
Original print shading	______

Directions: On B size vellum or other media selected by your instructor, construct an oblique drawing of one of the problems from Assignment Sheet 1. Use pencil or ink, and draw to appropriate scale. You will need to select a type of oblique such as cavalier, cabinet, or general. Make two quality blueline prints of your oblique and shade each oblique with a different type of shading. Shade your original with the **best** shading, and then turn in the blueline prints and the original to your instructor for evaluation.

CAD Alert: Use a CAD system to construct a 3D wireframe of a problem from Assignment Sheet 1, and project a copy of the surface up to the right at a 45° angle. Correct lines, delete hidden lines, and shade.

Presentation Drawings
Unit 6

Assignment Sheet 6—Construct a Two-Point Perspective Presentation Drawing

Name ________________________ Overall Rating ________

Evaluation criteria	**Rating**
Basic two point perspective	______
Blueline print shading	______
Original print shading	______

Directions: On B size vellum or other media selected by your instructor, construct a two-point perspective of one of the problems from Assignment Sheet 1. Use pencil and ink, and draw to appropriate scale. You will need to select vanishing and station points. Make two quality blueline prints, and shade each print with a different type of shading. Shade the original with **best** shading, and turn in the blueline prints and the original to your instructor for evaluation.

CAD Alert: Use a CAD system to construct a 2-point perspective from one of the problems in Assignment Sheet 1, and shade appropriately.

Presentation Drawings
Unit 6

Assignment Sheet 7—Construct an Exploded Assembly Presentation Drawing

Name ______________________ Overall Rating __________

Evaluation criteria	Rating
Basic exploded assembly presentation drawing	______
Blueline print quality	______
Original drawing quality	______

Directions: On D size vellum or media selected by your instructor, construct an exploded assembly drawing of problem selected by your instructor. Use pencil or ink and draw to appropriate scale. Include in your exploded assembly: 1—selected shading, 2—parts identification, 3—parts list, and 4—flow lines. You will need to select an appropriate scale and the type of pictorial (axonometric, oblique, or perspective) you want to draw. Make a blueline print of your completed drawing and turn the blueline and your original in to your instructor for evaluation.

CAD Alert: Use a CAD system to construct a 3D wireframe of a problem selected by your instructor. Reassemble all wireframes in their respective positions, delete hidden lines and follow instructions for making an exploded view. Use 2D or 3D third-party software for standard hardware. You can make a larger, more complex drawing with CAD.

Central
Steel
Wire Company

Materials and Specifications
Unit 7

Objective Sheet

Unit Objective

After completing this unit, the student should be able to determine wire and sheet metal sizes from gage numbers and select materials from a materials stock book. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to materials and specifications with their correct definitions.
2. Match professional organizations and their abbreviations with their activities.
3. Select true statements about specifications used on mechanical drawings.
4. Match basic metal heat treatments with their characteristics.
5. Match surface hardening treatments with their characterics.
6. Complete statements about forms of carbon steel.
7. Select categories of pipe usage.
8. Complete a list of spcifications for tubing callouts.
9. Match structural steel shapes with their specifications.
10. List standard mill sizes.
11. Match metal properties with their definitions.
12. Select true statements about guidelines for selecting materials.

Objective Sheet

13. Select true statements about metal characteristics and types.
14. Select true statements about types of ferrous manufacturing metals.
15. Solve problems about parts of the steel numbering system.
16. Select true statements about basic copper-type metals.
17. Match conditions of aluminum with their designations.
18. Match original aluminum alloys with their modifiers.
19. Distinguish between advantages and disadvantages of aluminum.
20. Distinguish between advantages and disadvantages of zinc.
21. Differentiate between types of plastics and their characteristics.
22. Distinguish between advantages and disadvantages of plastics.
23. Match refractories with their applications.
24. Determine wire and sheet metal size from gage numbers. (Assignment Sheet 1)
25. Select materials from a materials stock book. (Assignment Sheet 2)

Materials and Specifications
Unit 7

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for enrichment of exceptional students as well as accommodation of special needs students.

4. Make transparencies from the transparency masters included with this unit. These appear in the teacher edition only and are designed to be used with the following objectives:

   TM 1—Steel Numbering System (Objective 15)
   TM 2—Aluminum Alloy Numbering System (Objective 16)

5. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.

6. Develop teaching plan. Adjust for different learning styles.

7. Make copies of Unit Evaluation Form.

Delivery and Application

8. Provide students with unit of instruction.

9. Discuss unit and specific objectives.

10. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

11. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Suggested Activities

Evaluation

12. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

13. Make copies of the written test. Add or modify test items as needed.

14. Give written test.

15. Compile assignment sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignments.

16. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Utilize this entire unit to relate materials and specifications to industrial processes. Point out the significance of specifications in all phases of manufacturing, from planning to production. Invite a local manufacturing industry to send a representative to talk to students about this important element in mechanical drafting with CAD. Skill areas: **Learning skills, learning to learn**.

2. Use Objectives 12 and 13 to reinforce the importance of the relationship between drafting and manufacturing. Have samples of how area or local design engineers select materials which they use, and discuss the techniques that lead to selecting the right materials. Skill areas: **Communications skills, listening**.

3. Have samples ready to demonstrate some of the plastics discussed in Objectives 22 and 23. Have students list items they have with them that are made of plastic. Divide class into teams and assign each team to look for plastics in specific places. Have one team look around an automobile, another in the school cafeteria kitchen, another in the business office. Skill areas: **Group effectiveness, teamwork**.

Suggested Activities

4. Be sure that you have a suitable stock list or stock catalog available so students can complete Assignment Sheet 2. Items in the assignment sheet have been prepared from the *Central Steel and Wire Company Stock List* which is one of the most complete catalogs available. It is available from Central Steel in Chicago free of charge pending certain conditions. The book is intended for Central clients and is published annually. There are normally catalogs left at the end of the year, so Central will make these available to instructors at no cost, as long as your request is sent in november or early December. Be sure to write your request using school stationery with letterhead. If you require information, call:

   312-471-3800, extension 5916, or write:

   Publications Department
   Central Steel and Wire Company
   3000 West 51st Street
   Chicago, IL 60632

5. There are other catalogs that will serve student requirements for Assignment Sheet 2, and their names and ordering information are presented in the supplementary resources that follow this section.

Resources Used in Developing This Unit

1. *Central Steel & Wire Company.* Chicago, IL: Central Steel and Wire Company, 1993.
2. *Materials Engineering Materials Selector.* Cleveland, OH: Penton Publishing, 1992.
3. *Metals Reference Book*, 2nd Ed. Materials Park, OH: American Society of Metals, 1993.
4. *Stock List and Data Book.* Chicago, IL: Joseph T. Ryerson & Son, Inc., 1991.
5. *Sweet's Catalog File.* New York: McGraw Hill/Sweets Division, 1993.

Suggested Activities

Suggested Supplemental Resources

1. The *Metals Reference Handbook*, 2nd Ed. is a 560-page text that normally sells for $102.00. It is available with an educational discount of 50%. Write on stationery with the school letterhead, indicating the name of your program and number of students in the class. Mail to:

   Publications Department
   American Socity of Metals
   Materials Park, OH 44073

   or phone: 216-338-5151 and ask for Publications Department.

2. *Materials Engineering Materials Selector* costs $50.00, and is available from:

   Penton Publishing
   1100 Superior Avenue
   Cleveland, OH 44114

3. The *Stock List and Data Book* is only $5.00, and is available from:

   Advertising Department
   Ryerson Steel
   2621 W. 15th Place
   Chicago, IL 60608

   or phone: 312-762-2121 and ask for Advertising Department.

4. *Tool & Manufacturing Engineers Handbook, Vol 1: Machining*, 4th Ed. New York: The Socity of Manufacturing Engineers, 1983.

5. *Tool & Manufacturing Engineers Handbook, Vol. 2: Forming*, 4th Ed. New York: The Society of Manufacturing Engineers, 1984.

6. *Tool & Manufacturing Engineers Handbook, Vol. 3: Materials & Finishing*, 4th Ed. New York: The Society of Manufacturing Engineers, 1985.

7. *Tool & Manufacturing Engineers Handbook, Vol. 4: Quality Control & Assembly*. New York: The Society of Manufacturing Engineers, 1986.

8. *Tools & Manufacturing Engineers Handbook, Vol. 5: Manufacturing & Management*. New York: The Society of Manufacturing Engineers, 1988.

9. *Tools & Manufcaturing Engineers Handbook, Vol 6: Design for Manufacturability*. New York: The Society of Manufacturing Engineers, 1992.

Materials and Specifications
Unit 7

Answers to Assignment Sheets

Assignment Sheet 1

Note: Depending on reference material, answers may vary slightly.

A. .148
B. .0269
C. .00500
D. .0090

Assignment Sheet 2

Note: Depending on reference material, answers may vary slightly. The following references are from the *1992-93 Central Steel and Wire Company* catalog.

A. 1. 36 x 120 (reference p. 36)
   2. 37.50

B. 1. .063 x 48 x 144 (reference p. 155)
   2. 42.24#

C. 1. 5/16 x 96 (reference p. 17)
   2. 102.08#/Foot
      3′ x 103.08 = 306.24#

D. 1. 2.045#/Foot (reference p. 47)
   2. 20′

E. 1. 4.5#/Foot (reference p. 13)
   2. 20′ and 40′

F. 1. W18 x 55 (reference p. 10)
   2. 55#

G. 1. .375 (reference p. 102)
   2. 10.01#.Foot

Materials and Specifications
Unit 7

Answers to Written Test

1. a. 5 e. 10 i. 1
b. 6 f. 3 j. 7
c. 2 g. 8 k. 4
d. 9 h. 11

2. a. 2 e. 6
b. 5 f. 1
c. 7 g. 3
d. 4

3. a, b, c, e, f, g, i

4. a. 3
b. 1
c. 4
d. 2

5. a. 3 d. 2
b. 5 e. 4
c. 1

6. a. Commercial
b. Flatten
c. Special
d. Flats

7. a, b, c

8. a. Outside
b. Inside
c. Wall

9. a. 4 d. 2 or 3
b. 1 e. 2 or 3
c. 5

Answers to Written Test

10. Any seven of the following in any order:

a. Foil
b. Strip
c. Sheet
d. Plates
e. Bar
f. Rod
g. Wire
h. Tubing
i. Angle
j. Channel
k. I beam
l. Expanded sheet
j. Perforated sheet
k. Coils

11. a. 3 d. 5
b. 6 e. 1
c. 2 f. 4

12. a, b, d

13. a. Toughness
b. Ductility
c. Chip removal
d. Formability
e. Joinability

14. a, c, d, e

15. a. (1)
b. (3)
c. (2)

16. a, b

17. b

18. a. 4 d. 1
b. 5 e. 3
c. 2

19. a. 6 d. 3 g. 7
b. 4 d. 3 h. 1
c. 2 f. 9 i. 5

Answers to Written Test

20. b, c, e, f

21. a, c, d

22. b

23. b, c, e

24. a. 3
    b. 4
    c. 1
    d. 5
    e. 2

Materials and Specifications
Unit 7

Written Test

Name ______________________ Date ______________ Score __________

1. Match the terms on the right with their correct definitions.

______a. The ability of a metal to stretch and flow without breaking under pressure

______b. Metals such as steel that are primarily composed of iron

______c. The process of heating, then cooling a metal to obtain certain characteristics

______d. Substances such as cement or glass that have no animal, vegetable, or carbon content

______e. The relative difficulty of machining a metal

______f. Metals such as aluminum or copper that do not contain iron

______g. Substances such as leather and wood that have animal, vegetable, or carbon content

______h. Materials that have a high melting point

______i. Plastic which repeatedly softens when subjected to heat

______j. Plastic which permanently sets or hardens after exposure to heat

______k. The ability of a metal to resist rough treatment

1. Thermoplastic
2. Heat treatment
3. Nonferrous metals
4. Toughness
5. Ductility
6. Ferrous metals
7. Thermosetting
8. Organic materials
9. Inorganic materials
10. Machinability
11. Refactories

Written Test

2. Match professional organizations and their abbreviations with their activities. Place the number of the organization in the blank beside the description of its activities.

_______a. Issues steel specifications for the steel working industry

_______b. Coordiantes standards development and resolves standards problems for the United States

_______c. Issues steel plate specifications

_______d. Writes specifications for all materials

_______e. A standard designation system by AISI, SAE, ASTM, ASME, or UNS

_______f. Issues steel bar specifications

_______g. Unified National Standard for metals

1. SAE
2. AISI
3. UNS
4. ASTM
5. ANSI
6. Materials Classification System
7. ASME

3. Select true statements about specifications used on mechanical drawings. Place an "X" beside each true statement.

_______a. Material specifications name the material, such as cast iron, and may name a reference standard such as AISIC 13 400 or 7178-T6.

_______b. Finish specification can vary from rough to super fine.

_______c. General tolerances may be expressed in inches, ± 1/64 or in decimals, XXX = ± .002.

_______d. Color will be specified on all drawings.

_______e. Heat treatment deals with how basic metals are prepared, such as case hardened.

_______f. Number required will relate how many items are needed.

_______g. Hardness will reflect metal characteristics such as Rockwell "C" Scale.

_______h. Weight will always be specified.

_______i. Manufacturing will specify such items as drilling, reaming, or broaching.

Written Test

4. Match basic metal heat treatments with their characteristics. Place the number of the treatment in the blank beside the description of its characteristics.

______a. Softens metal and relieves stress

______b. Hardens by dipping heated metal in oil, water, air, or brine

______c. Reduces internal stress by reheating

______d. Hardens surface while leaving the inside soft

1. Hardening
2. Surface hardening
3. Annealing
4. Tempering

5. Match surface hardening treatments with their characteristics. Place the number of the treatment in the blanks beside the description of its characteristics.

______a. Introduces carbon to the metal surface

______b. Introduces carbon and nitrogen to the metal surface

______c. Introduces nitrogen to the metal surface

______d. Electrically heats the metal surface before the metal is quenched

______e. Heats the metal surface with a flame before quenching

1. Nitriding
2. Induction hardening
3. Carburizing
4. Flame hardening
5. Cyaniding

6. Complete statements about forms of carbon steel. Circle the information that best completes each of the following statements.

   a. Cold-rolled steel sheets come in a (**commercial**) (**welding**) quality for bending, forming, and welding, and in a drawing or better quality for severe forming or drawing.

   b. Carbon steel plates come as rectangles or coils, but the coils are difficult to (**handle**) (**flatten**) for process, so they are rarely used.

   c. Hot-rolled carbon steel bars are available as rounds, squares, flats, half rounds, and half ovals, and come in merchant quality or (**special**) (**commercial**) quality.

   d. Cold-rolled carbon steel bars come in rounds, hexagons, squares, and (**flats**) (**half rounds**).

Written Test

7. Select categories of pipe usage. Place an "X" beside each listing that indicates a category of pipe usage.

_______a. Pressure pipe

_______b. Structural and mechanical pipe

_______c. Standard pipe

_______d. Commercial pipe

8. Complete the following list of specifications for tubing callouts. Place the correct information in each of the blanks.

a. _______________ diameter

b. _______________ diameter

c. _______________ thickness

9. Match structural steel shapes with their specifications. Place the number of the shape in the blank beside the description of its specifications.

_______a. Depth of the section and by weight

_______b. Length of legs and weight per foot

_______c. Width of flange, overalls depth of stem, and weight per foot

_______d. Depth of section, flange width, and weight per foot

_______e. Depth of section, flange width, and weight per foot

1. Angles
2. Zees
3. Wide flange sections
4. Beams, columns, and channels
5. Tees

Written Test

10. List seven of the 14 different standard mill forms. Entries may be in any order in the blanks that follow.

a. ____________________

b. ____________________

c. ____________________

d. ____________________

e. ____________________

f. ____________________

g. ____________________

11. Match metal properties with their definitions. Place the number of the property in the blank beside its definition.

______a. Maximum load divided by cross sectional area just before straining when tensile loading a specimen

______b. Maximum stress that a material can withstand during compression just before deformation

______c. Maximum load in twisting action just before deformation

______d. Stress required to produce a fracture across a plane perpendicular to the cross section, the direction of forces and resistance being opposite and parallel with the paths offset a small amount

______e. Maximum stress at which fracture occurs during bending; also known as modulus of rupture

______f. Measure of the rigidity of a metal; the ratio of stress to strain

1. Bend strength
2. Torsional strength
3. Tensile strength
4. Modulus of elasticity
5. Shear strength
6. Compressive strength

Written Test

12. Select true statements about guidelines for selecting materials. Place an "X" beside each true statement.

_____a. The most important factor in selecting materials is to select materials with the lowest cost and the highest number of desirable characteristics.

_____b. Costs vary with the quantity of materials purchased, and the price per pound when purchased by the pound will probably be higher than the cost per pound when purchased by the ton.

_____c. Materials sometimes need to be purchased when they are on sale.

_____d. Purchase materials that have the qualities that will best serve the manufacturing process it is purchased for; these qualities include such elements as strength, surface finish, machinability, and corrosion resistance.

13. Complete statements about metal characteristics and types. Circle the material that best completes each of the following statements.

a. The physical characteristics of metals consider such things as (**strength**) (**toughness**) to shock loading, the rigidity required to resist force, and the loading ability to handle weight and stress.

b. Other physical charactersitics of metals include the strength to withstand great force and the (**machinability**) (**ductility**) required for a metal that can be drawn or rolled without breaking.

c. Machinability is an important manufacturing characteristic of metal because this measures the east or difficulty for (**rolling**) (**chip removal**).

d. (**Weldability**) (**Formability**), the ease of plastic flow, and castability, the ease of forming into parts, are two more metal manufacturing characteristics.

e. Another manufacturing characteristic, (**handling ease**) (**joinability**), measures the ease with which a metal can be joined mechanically or by welding or adhesives.

14. Select true statements about types of ferrous manufacturing metals. Place an "X" beside each true statement.

_____a. Cast iron is a common manufacturing metal and cast iron varieities include: gray cast iron, white cast iron, malleable iron, ductile or modular iron, and alloy cast iron.

_____b. Carbon steel comes in three types, low carbon steel, medium carbon steel, and tool steel.

Written Test

______c. Low carbon steel or mild steel is .05 to .30% carbon, and is used for forged and machined parts; it may not be hardened.

______d. Medium carbon steel is .30 to .60% carbon which makes it harder than mild steel, and it is easy to forge and machine.

______e. High carbon steel is .60 to 1.5% carbon, is hardened by heat treatment, and is easy to machine, weld, and forge.

______f. Alloy steel comes in three grades, low allow, medium allow, and high alloy.

15. Solve problems about parts of the steel numbering system. Circle the number of the statement that best solves each of the following problems.

ASME C 8 62 0

a. Plate steel has arrived at a shop and you have been asked to help a coworker identify what type of steel it is. The ID number is printed above. As you read the number you should know that the steel is:

(1) Classified by ASME and produced by the open hearth process.

(2) Classified by ASME and produced by the Bessemer process.

b. Other numbers in the ID indicate that it is:

(1) A low carbon steel with no alloys.

(2) A high carbon steel with no alloys.

(3) A high carbon steel alloyed with Nickel-Chromium-Molybdenum.

c. The carbon content is:

(1) 20% carbon

(2) .20% carbon

(3) 86% carbon

Written Test

16. Select true statements about basic copper type metals. Place an "X" beside each true statement.

    ______a. In addition to copper itself, other copper-type metals include brass and leaded brass.

    ______b. Also in the copper-type class are varieties of bronze, phosphor bronze, aluminum bronze, and silicon bronze.

    ______c. Others in the copper-type class include beryllium, cupro nickel, and chromium.

17. Solve a problem about the aluminum alloy numbering system. Circle the letter of the statement that best solves the following problem.

    2180-T6

    a. The 80 simply means that the metal is 80 percent aluminum.

    b. The 80 means that the metal is 99.80% aluminum.

18. Match conditions of aluminum with their designations. Place the number of the designation in the blank beside the condition.

______a. Fabricated	1. W
______b. Annealed	2. H
______c. Strain hardened	3. T
______d. Solution treated	4. F
______e. Special conditions	5. O

Written Test

19. Match original aluminum alloys with their modifiers. Place the number of the alloy in the blank beside its modifier.

______a. 1XXX

______b. 2XXX

______c. 3XXX

______d. 4XXX

______e. 5XXX

______f. 6XXX

______g. 7XXX

______h. 8XXX

______i. 9XXX

1. Other elements
2. Manganese
3. Silicon
4. Copper
5. Unused series
6. Aluminum
7. Zinc
8. Magnesium
9. Magnesium and silicon

20. Distinguish between advantages and disadvantages of aluminum. Place an "X" in the blanks beside advantages.

______a. Alkalis are corrosive to aluminum

______b. Electrical and thermal conductivity

______c. Ease of fabrication

______d. Loses parts of strength at elevated temperatures

______e. Light compared to steel

______f. Non-sparking and non-magnetic

Written Test

21. Distinguish between advantages and disadvantages of zinc. Place an "X" in the blanks beside advantages.

_______a. High production rate

_______b. Toxic—Cannot be used for food packaging

_______c. Easier to cast than aluminum because of a lower melting point

_______d. Resistance to atmospheric corrosion

_______e. Two to three times heavier than aluminum in equivalent die castings

22. Differentiate between types of plastics and their characteristics. Place an "X" beside the definition of thermosetting plastics.

_______a. A group of plastics that can be reheated to soften them

_______b. A group of plastics that will not soften with reheating

23. Distinguish between advantages and disadvantages of plastics. Place an "X" in the blanks beside advantages.

_______a. Are more dimensionally sensitive to temperature changes

_______b. Machine easier and faster

_______c. Often outlast metals in corrosive environments

_______d. Have lower load carrying capacity

_______e. Dampen shock vibration and noise

24. Match refractories with their applications. Place the number of the refractory in the blank beside its application.

______a. Used on all types of structures

______b. Used for windows

______c. Used in furnace parts and rocket nozzles

______d. Used in heat shields for space re-entry vehicles

______e. Used in both normal and high temperature applications

1. Aluminum
2. Ceramics
3. Concrete
4. Glass
5. Graphite

*Permission to duplicate this test is granted.

Materials and Specifications
Unit 7

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Determine Wire and Sheet Metal Size From Gage Numbers Rating ______

Comments: ____

____

Assignment Sheet 2—Select Materials From a Materials Stock Book Rating ______

Comments: ____

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

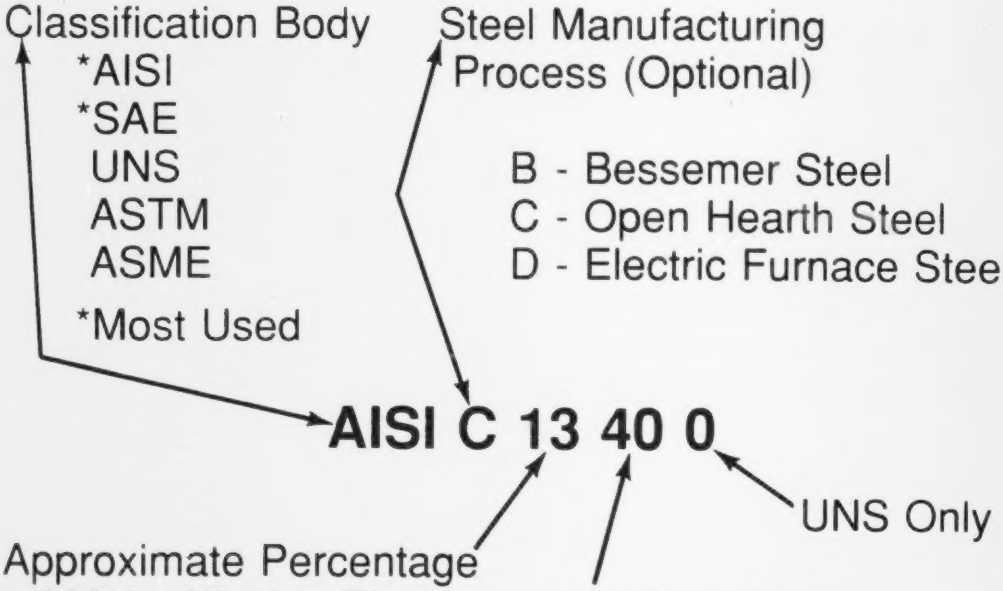
____

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

*Permission to duplicate this form is granted.

Steel Numbering System



Classification Body
*AISI
*SAE
UNS
ASTM
ASME

*Most Used

Steel Manufacturing
Process (Optional)

B - Bessemer Steel
C - Open Hearth Steel
D - Electric Furnace Steel

AISI C 13 40 0

UNS Only

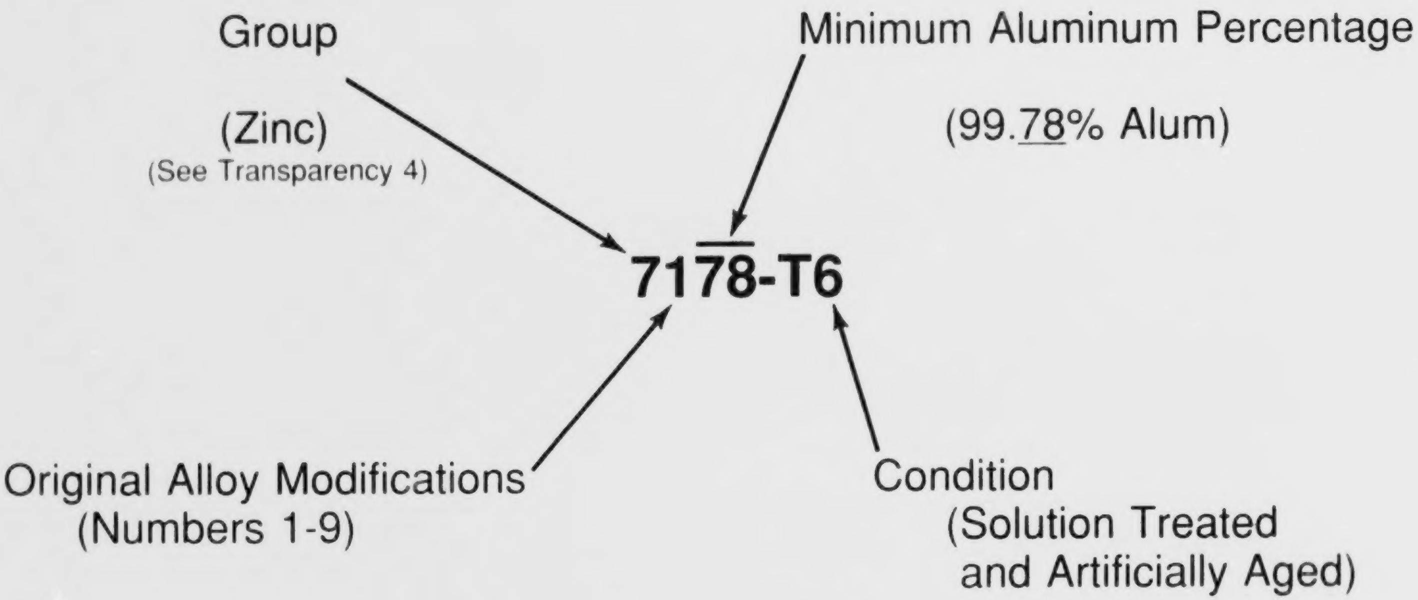
Approximate Percentage
of Main Alloying Element

- 10XX - Plain Carbon
- 11XX - Lead-Free Machining Steel
- 13XX - Manganese
- 2XXX - Nickel
- 3XXX - Nickel and Chromium
- 4XXX - Molybdenum
- 5XXX - Chromium
- 6XXX - Chromium-Vanadium
- 7XXX - Tungsten
- 8XXX - Nickel-Chromium-Molybdenum
- 9XXX - Manganese-Silicon

Carbon Content
(Hundredths of
One Percent)

.4% Carbon

Aluminum Alloy Numbering System



Group

(Zinc)
(See Transparency 4)

Minimum Aluminum Percentage

(99.$\underline{78}$% Alum)

71$\overline{78}$-T6

Original Alloy Modifications
(Numbers 1-9)

Condition
(Solution Treated
and Artificially Aged)

Mechanical Drafting With CAD. Unit 7
Teacher Page 27

Materials and Specifications
Unit 7

Information Sheet

1. **Terms and definitions**

   a. **Ductility** — The ability of a metal to stretch and flow without breaking under pressure

   b. **Ferrous metals** — Metals such as steel that are primarily composed of iron

   c. **Heat treatement** — The process of heating, then cooling a metal to obtain certain characteristics

   d. **Inorganic materials** — Substances such as cement or glass that have no animal, vegetable, or carbon content

   e. **Machinability** — The relative difficulty of machining a metal

   f. **Nonferrous metals** — Metals such as aluminum or copper that do not contain iron

   g. **Organic materials** — Substances such as leather and wood that have animal, vegetable, or carbon content

   h. **Refactories** — Materials that have a high melting point

   i. **Thermmoplastic** — Plastic which repeatedly softens when subjected to heat

   j. **Thermosetting** — Plastic which permanently sets or hardens after exposure to heat

   k. **Toughness** — The ability of a metal to resist rough treatment

Information Sheet

2. **Professional organizations, their abbreviations and activities**

   a. **AISI (American iron and Steel Institute** — Issues steel specifications for the steel working industry.

   b. **ANSI (American National Standards Institute)** — Coordiantes standards development and resolves standards problems for the United States

   c. **ASME (American Society of Mechanical Engineers)** — Issues steel plate specifications

   d. **ASTM (American Society for Testing Materials)** — Writes specifications for all materials

   e. **Materials Classification System** — A standard designation system by AISI, SAE, ASTM, ASME, or UNS

   f. **SAE (Society of Automotive Engineers)** — Issues steel bar specifications

   g. **UNS** — Unified National Standard for metals

3. **Specifications used on mechanical drawings**

   a. Material specifications name the material, such as cast iron, and may name a reference standard such as AISIC 13 400 or 7178-T6.

   b. Finish specification can vary from rough to super fine.

   c. General tolerances may be expressed in inches, ± 1/64 or in decimals, XXX = ± .002.

   d. Color will be specified when it is important.

   e. Heat treatment deals with how basic metals are prepared, such as case hardened.

   f. Number required will relate how many items are needed.

   g. Hardness will reflect metal characterisitcs such as rockwell "C" Scale.

   h. Weight will be specified when required.

   i. Manufacturing process will specify such items as drilling, reaming, or broaching.

   Note: Specifications may be required depending on the organizational structure of the manufacturing department.

Information Sheet

4. **Basic metal heat treatments and their characteristics**

   a. **Annealing** — Softens metal and relieves stress

   b. **Hardening** — Hardens by dipping heated metal in oil, water, air, or brine

   c. **Tempering** — Reduces internal stress by reheating

   d. **Surface hardening** — Hardens surface while leaving the inside soft

5. **Surface hardening treatments and their characteristics**

   a. **Carburizing** — Introduces carbon to the metal surface

   b. **Cyaniding** — Introduces carbon and nitrogen to the metal surface

   c. **Nitriding** — Introduces nitrogen to the metal surface

   d. **Induction hardening** — Electrically heats the metal surface before the metal is quenched

   e. **Flame hardening** — Heats the metal surface with a flame before quenching

6. **Forms of carbon steel**

   a. Cold-rolled steel sheets come in a commercial quality for bending,forming, and welding, and in a drawing or better quality for severe forming or drawing.

   b. Carbon steel plates come as rectangles or coils, but the coils are difficult to flatten for process, so they are rarely used.

   c. Hot-rolled carbon steel bars are available as rounds, squares, flats, half rounds, and half ovals, and come in merchant quality or special quality.

   d. Cold-rolled carbon steel bars come in rounds, hexagons, squares, and flats.

7. **Categories of pipe usage**

   a. Pressure pipe

   b. Structural and mechanical pipe

   c. Standard pipe

Information Sheet

8. **Specifications for tubing callouts**
    - a. Outside diameter
    - b. Inside diameter
    - c. Wall thickness
9. **Structural steel shapes and their specifications**
    - a. **Beams, columns, and channels**—Depth of the section and by weight
    - b. **Angles**—Length of legs and weight per foot
    - c. **Tees**—Width of blange, overall depth of stem, and weight per foot
    - d. **Zees**—Depth of section, flange width, and weight per foot
    - e. **Wide flange sections**—Depth of section, flange width, and weight per foot
10. **Standard mill forms and their standard mill sizes**
    - a. **Foil**—.0002" to .0055" thick, 7" to 36" wide
    - b. **Strip**—1/16" thick 1/4" to 12" wide
    - c. **Sheet**—18 gage (.0478) to 7 gage (.1793), 24" to 72" wide
    - d. **Plates**—3/16 to 12" thick, 9" to 120" wide
    - e. **Bar**—1/4 to 6" square, 1/4 to 4" hexagon, up to 12' length
    - f. **Rod**—7/32 to 4 7/16" diameter
    - g. **Wire**—.004 to .625" diameter
    - h. **Tubing**—1/32 to 24" OD, .004" to 3" thick walls
    - i. **Angle**—Leg 1/2" to 9", up to 80' long
    - j. **Channel**—Depth 3" to 18", 4.1#/foot to 42.7#./foot, 20'-60' long
    - k. **I Beam**—Depth 3" to 24", 5.7#/foot to 100#/foot, 20'-60' long
    - l. **Expanded sheet**—36 gage to 22 gage up to 72" x 144"
    - m. **Perforated sheet**—24 gage to 14 gage up to 48" x 120"

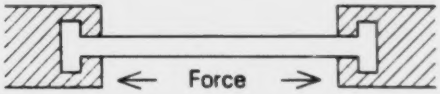
Information Sheet

n. **Coils**—.001 to .1793 thick general use; 1/4, 1/2 coiled for special material handling equipment-6" - 60" wide

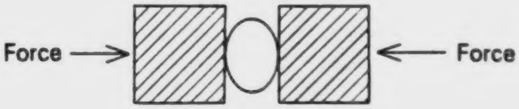
Note: Refer to a materials selector guide for reference to finished stock sizes. Standard mill sizes given above are for general reference so you'll get a better idea of material size and shape.

11. Metal properties and their definitions

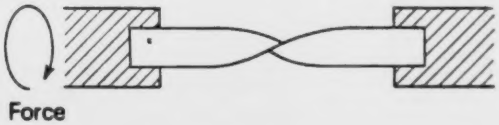
a. **Tensile strength**—Maximum load divided by cross sectional area just before straining when tensile loading a specimen



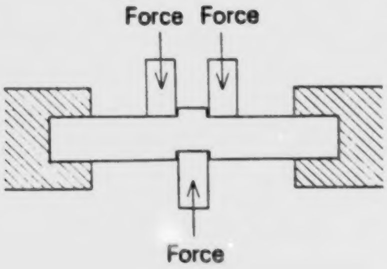
b. **Compressive strength**—Maximum stress that a material can withstand during compression just before deformation



c. **Torsional strength**—Maximum load in twisting action just before deformation

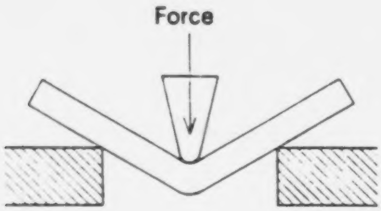


d. **Shear strength**—Stress required to produce a fracture across a plane perpendicular to the cross section, the direction of forces and resistance being opposite and parallel with the paths offset a small amount



Information Sheet

e. **Bend strength**—Maximum stress at which fracture occurs during bending; also known as modulus of rupture



f. **Modulus of elasticity**—Measure of the rigidity of a metal; the ratio of stress to strain

12. Guidelines for selecting materials

a. The most important factor in selecting materials is to select materials with the lowest cost and the highest number of desirable characteristics.

b. Costs vary with the quantity of materials purchased, and the price per pound when purchased by the pound will probably be higher than the cost per pound when purchased by the ton.

c. Materials sometimes need to be purchased by the piece or per unit of strength.

d. Purchase materials that have the qualities that will best serve the manufacturing process it is purchased for; these qualities include such elements as strength, surface finish, machinability, and corrosion resistance.

13. Metal characteristics and types

a. The physical characteristics of metals consider such things as toughness to shock loading, the rigidity required to resist force, and the loading ability to handle weight and stress.

b. Other physical characteristics of metals include the strength to withstand great force and the ductility required for a metal that can be drawn or rolled without breaking.

Information Sheet

c. Machinability is an important manufacturing characteristic of metal because this measures the ease or difficulty for chip removal.

d. Formability, the ease of plastic flow, and castability, the ease of forming into parts are two more metal manufacturing characteristics.

e. Another manufacturing characteristic, joinability, measures the ease with which a metal can be joined mechanically or by welding or adhesives.

14. Types of ferrous manufacturing metals

a. Cast iron is a common manufacturing metal and cast iron varieties include: gray cast iron, white cast iron, malleable iron, ductile or modular iron, and alloy cast iron.

b. Carbon steel comes in three types, low carbon steel, medium carbon steel, and high carbon steel.

c. Low carbon steel or mild steel is .05 to .30% carbon, and is used for forged and machined parts; it may not be hardened.

d. Medium carbon steel is .30 to .60% carbon which makes it harder than mild steel, and it is easy to forge and machine.

e. High carbon steel is .60 to 1.5% carbon, is hardened by heat treatment, and is difficult to machine, weld, and forge.

f. Alloy steel comes in three grades, low alloy, medium alloy, and tool steels.

15. Parts of the steel numbering system

a. The steel numbering system starts on the far left with initials of the classifying body, such as AISI, SAE, or ASME.

b. The single letter entry to the right of the classification body identifies the type of steel manufacturing process such as B for Bessemer, C for open hearth, and D for electric furnace steel.

c. The next entry to the right of the manufacturing process identifies the approximate amount of alloying agent in alloy steel.

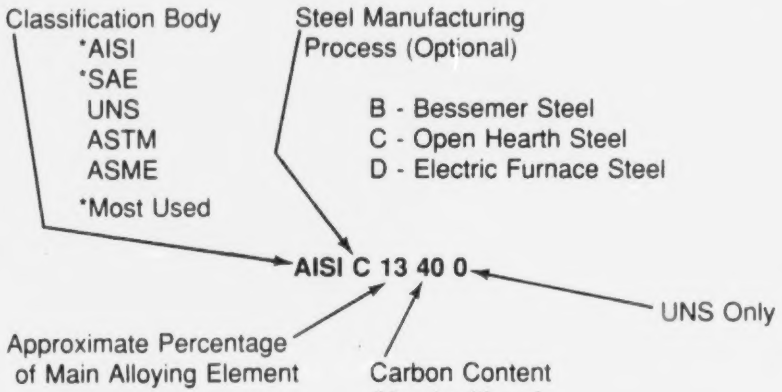
Example: 13 means .13% of main alloying agent.

d. The entry to the right of the allow content indicates the carbon content of the steel in hundredths of one percent.

Information Sheet

e. The final entry on the far right indicates a Unified National Standard, if one applies.

Steel Numbering System


Classification Body
*AISI
*SAE
UNS
ASTM
ASME
*Most Used
Steel Manufacturing Process (Optional)
B - Bessemer Steel
C - Open Hearth Steel
D - Electric Furnace Steel
AISI C 13 40 0
UNS Only
Approximate Percentage of Main Alloying Element
Carbon Content (Hundredths of One Percent)

10XX - Plain Carbon
11XX - Lead-Free Machining Steel
13XX - Manganese
2XXX - Nickel
3XXX - Nickel and Chromium
4XXX - Molybdenum
5XXX - Chromium
6XXX - Chromium-Vanadium
7XXX - Tungsten
8XXX - Nickel-Chromium-Molybdenum
9XXX - Manganese-Silicon

.4% Carbon

f. ASTM has an alternate numbering system based on mechanical properties.

Example: ASTM A 36 has a 36,000 PSI ultimate strength, but ASTM A 285 (the number 285) has no meaning except as reference to look it up in a mechanical properties manual.

Information Sheet

16. Basic copper-type metals

a. In addition to copper itself, other copper-type metals include brass and leaded brass.

b. Also in the copper-type class are varieties of bronze, phosphor bronze, aluminum bronze, and silicon bronze.

c. Others in the copper-type class include beryllium, cupro nickel, and nickel silver.

17. Parts of the aluminum alloy numbering system

a. The first number on the left of an aluminum ID indicates the group number of the alloy.

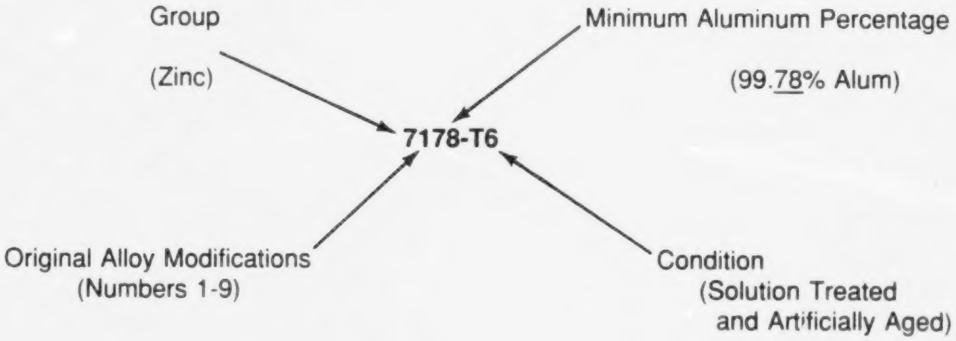
b. The second number to the right indicates the original alloy modifications.

Note: See Objective 18 for more information about aluminum alloys.

c. The center number under the bar indicates the minimum aluminum percentage.

d. The letter and number following the dash at the far left of the ID indicate manufacturing conditions.

Aluminum Alloy Numbering System


Group
(Zinc)
Minimum Aluminum Percentage
(99.78% Alum)
7178-T6
Original Alloy Modifications
(Numbers 1-9)
Condition
(Solution Treated
and Artificially Aged)

Information Sheet

18. **Conditions of aluminum and their designations**
    - a. **F**—Fabricated
    - b. **O**—Annealed
    - c. **H**—Strain hardened
    - d. **W**—Solution treated
    - e. **T (T3-T10)**—Special conditions

19. **Original aluminum alloys and their modifiers**
    - a. **Aluminum**—1XXX
    - b. **Copper**—2XXX
    - c. **Manganese**—3XXX
    - d. **Silicon**—4XXX
    - e. **Magnesium**—5XXX
    - f. **Magnesium and Silicon**—6XXX
    - g. **Zinc**—7XXX
    - h. **Other elements**—8XXX
    - i. **Unused series**—9XXX

20. **Advantages and disadvantages of aluminum**
    - a. Advantages
        - (1) Corrosion resistance
        - (2) Electrical and thermal conductivity
        - (3) Attractive appearance
        - (4) Light compared to steel, brass, nickel, or copper
        - (5) Load carrying capacities based on equal weight of material compares very favorably with steel

Information Sheet

(6) Ease of fabrication

(7) Non-sparking and non-magnetic

b. Disadvantages

(1) Loses part of strength at elevated temperatures

(2) Galvanic corrosion possible when in contact with other metals

(3) Alkalis are corrosive to aluminum

(4) Lower mechanical properties than those of steel when of equal cross section (not weight)

21. Advantages and disadvantages of zinc

a. Advantages

(1) Easier to cast than aluminum because its lower melting point

Note: Zinc is used in the automotive industry and general manufacturing because it is really easy to cast.

(2) Low cost

(3) High production rate

(4) Resistance to atmospheric corrosion

(5) Ability to provide galvanic protection to steel

b. Disadvantages

(1) Two or three times heavier than aluminum in equivalent die castings

(2) Not as dimensionally stable as aluminum castings

(3) Cannot be used for food packaging because it is toxic

Information Sheet

22. **Types of plastics and their characteristics**

    a. **Thermoplastic plastics**—A group of plastics that can be reheated to soften them

    Examples: Thermoplastic plastics include the acrylic resins used in sunscreens and windows, the polycarbonates used in safety glass, the polystyrenes used in drinking cups, the synthetic rubber used in tires, and many more.

    b. **Thermosetting plastics**—A group of plastics that will not soften with reheating

    Examples: Thermosetting plastics include the epoxides used for fastening, the melamine used in tableware, the polyesters used in sports car bodies, and many more.

23. **Advantages and disadvantages of plastics**

    a. Advantages

        (1) Often outlast metal equivalent parts at comparable speed and load

        (2) Often outlast metals in corrosive environments

        (3) Dampen shock vibration and noise

        (4) Can operate with little or no lubricant

        (5) Machine easier and faster

    b. Disadvantages

        (1) Are more dimensionally sensitive to temperature changes

        (2) Cannot be produced to as high precision tolerances as most metals

        (3) Have lower load carrying capacity

24. **Refactories and their applications**

    a. **Concrete**—Used on all types of structures

    b. **Glass**—Used for windows

    c. **Aluminum**—Used in furnace parts and rocket nozzles

    d. **Graphite**—Used in heat shields for space re-entry vehicles

    e. **Ceramics**—Used in both normal and high temperature applications

Materials and Specifications
Unit 7

Assignment Sheet 1—Determine Wire and Sheet Metal Size From Gage Numbers

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Number of problems attempted	______
Number of problems determined correctly	______

Directions: Use the standard wire and sheet gage charts included with this assignment sheet to determine wire and sheet metal size from gage number. Use the following example as a guideline.

Example: Find the size of a Birmingham wire #0000 gage

1. Go to standard wire gage chart attached
2. Read down "Gage No." column until 400's is reached; the 4-0's means 0000
3. Read across Birmingham column to where it intersects 4-0's column
4. Answer is .454

Problems:

A. Find the size of a Birminham wire # 9 gage

____

B. Find the size of a steel manufacturers' sheet #23 gage

____

C. Find the size of a Brown and Sharpe for nonferrous metals wire #36 gage

____

D. Find the size of an American Washburn & Moen Co.'s std steel wire #36 gage

____

Assignment Sheet 1

STANDARD WIRE & SHEET GAGES

WIRE GAGES
Decimal Inch Equivalent

SHEET GAGES

GAGE NO	BIRMINGHAM[1] WIRE GAGE (BWG) (Stubs Iron Gauge)	STEEL[2] WIRE GAGE (Washburn & Moen)	AMERICAN[3] WIRE GAGE (Brown & Sharpe)	STEEL SHEETS Thickness in Inches	ALUMINUM SHEETS Thickness in Inches	STAINLESS STEEL SHEETS Approx. Thickness in Inches	GALVANIZED SHEETS Thickness in Inches
40		0070	00314				
39		0075	00353				
38		0080	00396	0060	00396		
37		0085	00445	0064	00445		
36	004	0090	00500	0067	00500		
35	005	0095	00561	0075	00561		
34	007	0104	00630	0082	00630		
33	008	0118	00708	0090	00708		
32	009	0128	00795	0097	00795	010	0134
31	010	0132	00893	0105	00893	011	0142
30	012	0140	0100	0120	0100	013	0157
29	013	0150	0113	0135	0113	014	0172
28	014	0162	0126	0149	0126	016	0187
27	016	0173	0142	0164	0142	017	0202
26	018	0181	0159	0179	0159	019	0217
25	020	0204	0179	0209	0179	022	0247
24	022	0230	0201	0239	0201	025	0276
23	025	0258	0226	0269	0226	028	0306
22	028	0286	0253	0299	0253	031	0336
21	032	0317	0285	0329	0285	034	0366
20	035	0348	0320	0359	0320	038	0396
19	042	0410	0359	0418	0359	044	0456
18	049	0475	0403	0478	0403	050	0516
17	058	0540	0453	0538	0453	056	0575
16	065	0625	0508	0598	0508	063	0635
15	072	0720	0571	0673	0571	070	0710
14	083	0800	0641	0747	0641	078	0785
13	095	0915	0720	0897	0720	094	0934
12	109	1055	0808	1046	0808	109	1084
11	120	1205	0907	1196	0907	125	1233
10	134	1350	1019	1345	1019	141	1382
9	148	1483	1144	1495	1144	156	1532
8	165	1620	1285	1644	1285	172	1681
7	180	1770	1443	1793	1443		
6	203	1920	1620	1943	1620		
5	220	2070	1819	2092	1819		
4	238	2253	2043	2242	2043		
3	259	2437	2294	2391	2294		
2	284	2625	2576				
1	300	2830	2893				
0	340	3065	3249				
2-0's	380	3310	3648				
3-0's	425	3625	4096				
4-0's	454	3938	4600				
5-0's	500	4305	5165				
6-0's		4615	5800				
7-0's		4900					

1. Used for tubing wall thicknesses and certain strip and spring steel products
2. Used by virtually all manufacturers of *steel* wire in U.S.
3. Used for copper, brass, aluminum, and other nonferrous metals
4. Aluminum sheets use the same gage numbers as American Wire gage—order aluminum by thickness not gage

Materials and Specifications
Unit 7

Assignment Sheet 2—Select Materials From a Materials Stock Book

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Number of selection attempts	______
Number of selections correctly made	______

Directions: Use the *Centrol Steel and Wire Company Reference Book* or any comparable materials stock book to select materials for the problems that follow. Use the following example as a guideline.

Example: Select the standard sheet size length and width for 14 gage hot-rolled steel sheet ASTM A570, Grade 40 to fit a design 57″ by 143″. Consider the least amount of wasted material in your selection. Also find the estimated weight per sheet.

1. Go to standard materials stock book.
2. Read index of stock book for steel sheets.
3. Locate ASTM A 570, Grade 40, Hot Rolled Flat sheets.
4. Locate 14 gage thickness.
5. Locate sheet size that would fit a 57″ by 143″ design.
6. A 60″ by 144″ sheet is required.
7. Estimate of lbs. per sheet is 187.5#.

Problems:

A. Select the standard purchased sheet size length and width for 22 gage cold rolled commercial quality ASTM A366 steel sheet to fit a design 31″ by 97″. Consider the least amount of wasted material in your selection. Also find the estimated weight per sheet.

1. Sheet size length and width ______________________________
2. Estimated weight per sheet ______________________________

Assignment Sheet 2

B. Select the standard purchased sheet size length and width for .063 thick 5052-0 aluminum flat sheets ASTM B 209 with 1+32 mill finish to fit a design 45" by 85". Consider the least amount of wasted materials in your selection. Also find weight per sheet.

1. Sheet size length and width ______________________________
2. Estimated weight per sheet ______________________________

C. Select the standard purchased plate length and width for 5/16 thick steel plate ASTM A 515 GR 70 to fit a design 36" by 95". Consider the least amount of wasted materials in your selection. Also find weight per plate.

1. Plate size length and width ______________________________
2. Estimated weight per plate ______________________________

D. Select the standard purchased estimated weight per foot 1018 hexagon cold finished bar ASTM A576 of 7/8 inches across flats. Also find the random length.

1. Estimated weight per foot ______________________________
2. Stock length ______________________________

E. Select a bar size angle ASTM A 36 to fit a design need of 2 1/2" by 2" by 5/16 thick. What is the estimated weight per foot, and what lengths are available?

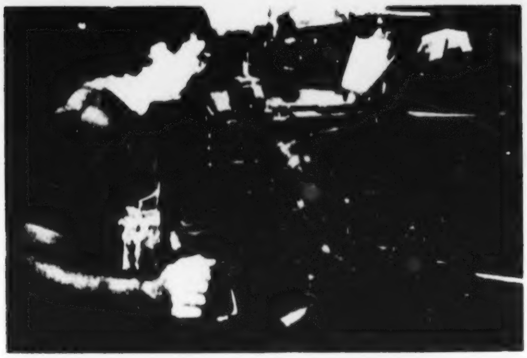
1. Estimated weight per foot ______________________________
2. Lengths available ______________________________

F. Select a wide flange structural beam ASTM A36 with a depth of 18.11", flange width 7.530" and web thickness of .390". Find the AISI designation and estimated weight per foot.

1. AISI designation ______________________________
2. Estimated weight per foot ______________________________

G. Select a carbon steel tubing—round seamless mechanical tubing cold drawn outside diamter (OD) 2 7/8 and inside diameter 2.125". Find the wall thickness and estimated weight per foot.

1. Wall thickness ______________________________
2. Estimated weight per foot ______________________________



Manufacturing Processes
Unit 8

Objective Sheet

Unit Objective

After completing this unit, the student should be able to calculate sheet metal bend allowance, design a casting part, design a forging part, design a welded part, and design a thermoplastic part. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to manufacturing processes with their definitions.
2. Match metal treatment processes with their characteristics.
3. Match production processes with their characteristics.
4. Complete a list of principal types of drawings for manufacturing processes.
5. Match casting terms with their definitions.
6. Complete statements about guidelines for designing a casting.
7. Match forging terms with their definitions.
8. Complete statements about guidelines for designing a forging.
9. Match welding terms with their definitions.
10. Select true statements about pattern and machine dimensions and their applications.
11. Select true statements about guidelines for designing a welded assembly.

Objective Sheet

12. Match types of machines with their uses.

13. Select true statements about the advantages of numerical control machinery.

14. Match plastic manufacturing terms with their definitions.

15. Match types of plastics with the methods for their fabrication.

16. Complete statements about guidelines for designing plastic products.

17. Match sheet metal processing terms with their definitions.

18. Identify sheet metal hems and joints.

19. Calculate bend allowance.

20. Calculate bend allowance for sheet metal. (Assignment Sheet 1)

21. Design a casting part. (Assignment Sheet 2)

22. Design a forging part. (Assignment Sheet 3)

23. Design a welded part. (Assignment Sheet 4)

24. Design a thermoplastic part. (Assignment Sheet 5)

Manufacturing Processes
Unit 8

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for enrichment of exceptional students as well as accommodation of special needs students.
4. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.
10. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Suggested Activities

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

12. Make copies of the written test. Add or modify test items as needed.

13. Give written test.

14. Compile assignment sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignments.

15. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Utilize this entire unit to relate drafting activities to industrial processes. Point out the significance of planning to success in all phases of manufacturing, from planning to production. Arrange to visit a local manufacturing facility and have students prepare a team report about the types of machines and processes observed. Skill area: **Group effectiveness skills, teamwork.**.

2. Make sure you have good examples of castings and forgings to show the class when you begin instructing Objectives 5 through 8. Discuss guidelines for designing both castings and forgings, and have a variety of projects available for students to select from to complete the assignment sheets. Skill area: **Communications skills, listening.**

3. Have the welding instructor from your school talk to the class about welding symbols and welding drawings. Ask the instructor to bring some good welding drawings and demonstrate to the class how a welder interprets symbols and other drawing elements. Skill area: **Communications skills, listening.**

Resources Used in Developing This Unit

1. Giesecke, Frederick E. *Technical Drawing*, 9th Ed. New York: Macmillan Publishing Company, 1991.

Suggested Activities

2. Jensen, Cecil and J. D. Helsel. *Engineering Drawing and Design*, 4th Ed. New York: Gregg Division/McGraw-Hill,, 1990.

3. Jensen, Cecil, et. al. *Computer-Aided Engineering Drawing Using AutoCAD*. New Jersey: Glencoe/McGraw-Hill, 1990.

4. Berins, M. *Plastics Engineering Handbook of the Society of the Plastics Industry*, 5th ed. New York: Van Nostrand Reinhold Co., 1991.

5. French, Thomas E., et. al. *Engineering Drawing and Graphic Technology*, 14th Ed. New York: McGraw Hill Book Co., 1993.

6. *The procedure Handbook of Arc Welding*, 12th Ed. Cleveland, OH: The Lincoln Electric Company, 1973.

7. O'Brien, R. L., ed. *Welding Handbook Eighth Edition, Vol. 2, Welding Processes*. Miami, FL: American Welding Society, 1991.

8. Armstead, B. H., et. al. *Manufacturing Processes*, 8th Ed. New York: John Wiley and Sons, 1987.

9. DeGarmo, E. Paul, J. T. Black, and R. A. Kohser. *Materials and Processes in Manufacturing*, 7th Ed. New York: Macmillan Publishing Company, 1993.

10. *Tool & Manufacturing Engineers Handbook, Vol. 1: Machining*, 4th Ed. New York: The Society of Manufacturing Engineers, 1983.

11. *Tool & Manufacturing Engineers Handbook, Vol. 2: Forming*, 4th Ed. New York: The Society of Manufacturing Engineers, 1984.

12. *Tool & Manufacturing Engineers Handbook, Vol. 3: Materials & Finishing*, 4th Ed. New York: The Society of Manufacturing Engineers, 1985.

Suggested Supplemental Resources

1. *Tool & Manufacturing Engineers Handbook, Vol. 4: Quality Control & Assembly*. New York: The Society of Manufacturing Engineers, 1986.

2. *Tools & Manufacturing Engineers Handbook, Vol. 5: Manufacturing & Management*. New York: The Society of Manufacturing Engineers, 1988.

3. *Tools & Manufacturing Engineers Handbook, Vol. 6: Design for Manufacturability*. New York: The Society of Manufacturing Engineers, 1992.

Manufacturing Processes
Unit 8

Answers to Assignment Sheets

Assignment Sheet 1

A. $[.017453 (.531) + .0078 (.025)] 90 = .852$

B. $[.017453 (.438) + .0078 (25)] 120 = 1.151$

C. $[.017453 (.094) + .0078 (.094)] 90 = .214$

D. $[.017453 (.25) + .0078 (.125)] 85 = .454$

E. $[.017453 (.031) + .0078 (.038)] 30 = .0251$

F. $[.017453 (.219) + .0078 (.025)] 120 = .482$

Assignment Sheets 2, 3, 4, and 5

Evaluated according to criteria written in the respective assignment sheets.

Manufacturing Processes
Unit 8

Answers to Written Test

1.

a.	4	e.	8	i.	10
b.	7	f.	3	j.	9
c.	5	g.	2	k.	11
d.	1	h.	6		

2.

a.	6	e.	1	i.	2
b.	5	f.	11	j.	10
c.	9	g.	7	k.	12
d.	8	h.	3	l.	4

3.

a.	3	e.	4
b.	6	f.	7
c.	8	g.	5
d.	1	h.	2

4. Items may appear in any order.

b.	Machining
c.	Welding
d.	Sheet metal
e.	Forging

5.

a.	6	e.	1	i.	3
b.	9	f.	7	j.	2
c.	4	g.	5		
d.	10	h.	8		

6.

a.	Abrupt
b.	Uniform
c.	Internal
d.	Minimum
e.	Rib thickness
f.	A thick member
g.	Opposite
h.	Withdrawing the pattern from the sand
i.	Shrink
j.	Draft or taper
k.	Finish
l.	Cylindrical

Answers to Written Test

7. a. 4
b. 2
c. 6
d. 5
e. 7
f. 1
g. 3

8. a. Away
b. Toward
c. Draft
d. Flow

9. a. 3
b. 7
c. 10
d. 11
e. 8
f. 5
g. 4
h. 1
i. 6
j. 9
k. 2

10. a

11. a, d, e, f, g, h, j

12. a. 6
b. 3
c. 5
d. 2
e. 7
f. 4
g. 1

13. a, b, d, e

14. a. 5
b. 3
c. 1
d. 4
e. 7
f. 2
g. 8
h. 6

15. a. 2
b. 3
c. 1

16. a. .130″
b. .016″
c. 4°
d. Fillets
e. 5°
f. 1/16″

17. a. 7
b. 8
c. 6
d. 5
e. 3
f. 1
g. 4
h. 9
i. 2

Answers to Written Test

18. a. Plain flat seam
    b. Standing seam
    c. Single seam
    d. Double flange

19. BA = .760
    Student work should show the equivalent of:
    BA = [(0.17453(.5) + .0078 (.1819)] (75)
    BA = [.0087265 + .0000141882] 75
    BA = .760

Manufacturing Processes
Unit 8

Written Test

Name ______________________________ Date ________________ Score __________

1. Match the terms on the right with their correct definitions. Definitions are continued on the following page.

______ a. A metal object formed by pouring molten metal into a mold and then allowing the metal to solidify

______ b. The process of pouring molten metal into a revolving mold

______ c. A special body designed to produce a special cavity in or on a casting

______ d. The process of forcing hot metal into a mold or a die

______ e. The process of pouring a sand mixture, called the investment, around a wax pattern; the casting is made by pouring molten metal into the hardened shell and melting and forcing the wax out

______ f. The form used to make a cavity in a sand mold

______ g. A casting produced with metal molds plus hydrostatic pressure

______ h. The process of using thin, sand resin shells molded of the pattern; molten metal is poured into the cavity

______ i. The process of compressing material in a die until it is formed into a new shape

______ j. A process that mixes metal powders, compresses them with high pressure and heats them at high temperature

______ k. Processes that remove material from or add material to an original part, or spread material to other areas of a part

1. Die casting
2. Permanent mold casting
3. Pattern
4. Casting
5. Core
6. Shell molding
7. Centrifugal casting
8. Investment casting
9. Powder metallurgy
10. Forging
11. Manufacturing processes

Written Test

2. Match metal treatment processes with their characteristics. Place the number of the process in the blank beside the definition of the process.

______ a. The use of an acid to dissolve metal in areas except where acid resist is used

______ b. The forming or plastic deforming of metal while the metal is cold

______ c. A pulsing technique using accelerated electrons that heat and cool an area

______ d. The process of removing material from a metal by reversing the electroplating process

______ e. The removal of metal with a spark in the presence of a coolant

______ f. A process of covering metal with electro-deposits of a thin coating of the same or other metal

______ g. A process of melting materials and blowing the melted metal onto a surface

______ h. Metal in a plastic state formed by mechanical working such as rolling or forging

______ i. The precise removal of small amounts of metal by using a concentrated focus of intense heat

______ j. Operations that change the shape, finish, or size by removing material from a workpiece

______ k. The bombardment of a workpiece with grit driven by linear oscillation of the tool

______ l. Using dies to form or cut metal sheets into a set form

1. Electronic discharge machining
2. Laser machining
3. Hot working metal
4. Ultrasonic machining
5. Cold working metal
6. Chemical machining
7. Flame spraying
8. Electro-chemical machining
9. Electron beam machining
10. Machining operations
11. Electroplating
12. Stamping

Written Test

3. Match production processes with their characteristics. Place the number of the process in the blank beside its definition.

_____a. A numerically controlled (NC) machine or system of machines that control the sequence of operations, tool movement or material movement with little, if any, assistance from an operator

_____b. A numerical control system that uses a special-purpose computer to operate machine tools

_____c. The process of pushing or forcing metal through a shape-formed die

_____d. The process of melting materials or melting materials together

_____e. The process of ramming hot plastic into a mold to form a shape

_____f. Operation of machine tools with automatic programmed cutting sequences using direct information or numerical data stored on paper, magnetic other media to produce accurate machining of complex geometrical surfaces

_____g. A mechanical or chemical process used to improve the resistance to wear, surface hardness, coatability, or appearance of a part

_____h. A machine that has the capability to transfer a workpiece from one operation to another operation in the same machine or to a different machine

1. Fusion
2. Transfer machine
3. Automation
4. Injection molding
5. Surface preparation
6. CNC machining
7. NC machining
8. Extrusion

Written Test

4. Complete the following list of principal types of drawings for manufacturing processes. Enter the correct items in any order in the blanks.

a. Casting

b. ____________________

c. ____________________

d. ____________________

e. ____________________

5. Match casting terms with their definitions. Place the number of the terms in the blank beside its definition.

_______a. Devices to align the drag and cope of a flask

_______b. The middle part of the flask

_______c. The top half of the flask

_______d. The pattern taper for easy removal of a pattern from a mold

_______e. The bottom half of the flask

_______f. The complete mold

_______g. Opening for molten metal for flow between the sprue and the mold cavity

_______h. The line where the mold separates

_______i. Relief that permits air and molten metal to rise

_______j. The tapered hole in the cope of a casting mold through which molten metal is poured into the mold cavity

1. Drag
2. Sprue
3. Riser
4. Cope
5. Gate
6. Alignment pins
7. Flask
8. Parting line
9. Cheek
10. Draft

Written Test

6. Complete statements about guidelines for designing a casting. Circle the material that best completes each of the following statements.

   a. Avoid (**excessive**) (**abrupt**) changes in a section.

   b. Keep the wall thickness of sections (**straight**) (**uniform**)

   c. Avoid creating (**internal**) (**external**) stress.

   d. Use a (**minimum**) (**maximum**) number of adjoining sections.

   e. Make fillet radii equal to (**4× wall thickness**) (**rib thickness**).

   f. Thicken thin membranes when they approach (**a thick member**) (**an outer wall**).

   g. Prevent stress along (**outside**) (**opposite**) spokes by designing with odd number instead of even number of spokes.

   h. Allow room for (**additional required treatments**) (**withdrawing the pattern from the stand**) after casting.

   i. Use a (**metric**) (**shrink**) rule to lay out patterns.

   j. Add a (**groove or channel**) (**draft or taper**) to the pattern to allow the casting to be removed from the mold.

   k. Provide extra metal or a (**handle**) (**finish**) allowance so the metal can be machined after casting.

   l. Use a boss, a (**horizontal**) (**cylindrical**) projection on the casting, to give a bearing surface to which a fastener can be attached.

7. Match forging terms with their definitions. Place the number of the term in the blank beside the definition.

______a. Device used in shaping or stamping an object for flat material

______b. The amount added to a die when dies do not close

______c. Taper of surfaces to allow easy removal from the die

1. Parting line
2. Die closure
3. Forging plane
4. Die
5. Flash

Written Test

______d. The slight excess that appears as a thin fin of material surrounding a forging at the parting line

______e. Measurement of the displacement of two opposing dies in the direction parallel to the parting line of the dies

______f. The line where dies meet and separate; also called a flash line

______g. The plane perpendicular to the direction of pressure

6. Draft
7. Match tolerance

8. Complete statements about guidelines for designing a forging. Circle the material that best completes each of the following statements.

   a. Avoid sharp corner fillets except when material is flowing (**away**) (**into**); fillets may be sharper.

   b. Design a large fillet if material is flowing (**away from**) (**toward**) the fillet.

   c. Use strippers and ejectors when little or no (**tolerance**) (**draft**) is used.

   d. Make the dies last longer by allowing generous tolerances for dies in areas of greatest pressure and (**contact**) (**flow**).

9. Match welding terms with their definitions. Place the number of the terms in the blank beside its definition.

______a. A method of testing welded samples by bending, breaking, or otherwise destroying the usefulness of the tested material

______b. A process where heated metals are forced together under pressure

______c. An arc welding process that produces coalescence of metals by heating then with an arc between a continuous filler metal electrode and a workpiece; shielding is obtained entirely from an externally applied gas

1. Oxyfuel gas welding
2. Thermit welding
3. Destructive testing
4. Plasma arc welding
5. Nondestructive testing
6. Resistance welding
7. Forge welding

Written Test

______d. An arc welding process that produces coalescence of materials by heating them with an arc between a nonconsumable tungsten electrode and a workpiece; shielding is obtained from a gas, and filler metal may or may not be used

______e. A process where electric current is used to heat and melt parts so that the parts fuse together; an economical high production welding process

______f. A method of testing welded materials with X-rays, magnetic particles, or even visually so that the usefulness of the material is not destroyed

______g. An arc welding process that produces coalescence of metals by heating them with a constricted arc between a nonconsumable electrode and a workpiece, or the electrode and a constricting nozzle

______h. A group of welding processes that produce coalescence by heating materials with an oxyfuel gas flame or flames, with or without pressure, and with or without filler metal

______i. The process of placing parts together, then passing a heavy current through them to make the metals melt and fuse together

______j. An arc welding process that produces coalescence of materials by heating them with an arc between a covered electrode and a workpiece; shielding is obtained from decomposition of the electrode cover, and filler metal is obtained from the electrode

8. Induction welding
9. Shielded metal arc welding
10. Gas metal arc welding
11. Gas tungsten arc welding

Written Test

______k. A process that weld metals together as a result of the chemical reaction between powdered aluminum and powdered metal oxide

10. Select true statements about pattern and machine dimensions and their applications. Place an "X" beside each true statement.

______a. Pattern dimensions are needed only by a pattern maker to make a pattern.

______b. Machine dimensions are needed only by a machinist to make a pattern.

11. Select true statements about guidelines for designing a welded assembly. Place an "X" beside each true statement.

______a. Use standard rolled shapes such as I beams, channels, zees,and tees.

______b. Design slightly above calculated load to handle the unexpected.

______c. Use shallow sections to avoid bending.

______d. Choose stiffeners properly to provide rigidity with less weight.

______e. Use closed sections or diagonal bracing to control torsion (twisting).

______f. Provide suitable access for maintenance.

______g. Design with minimum number of pieces.

______h. Eliminate beveling if a deep penetrating arc can be used.

______i. Use a maximum root opening to assure good penetration.

______j. Place welds on the shortest seams.

12. Match types of machines with their uses. Place the number of the machine in the blank beside the description of its use.

______a.	A machine that pulls or pushes a broaching tool over a workpiece surface to machine simple or complex contours	1. Lath 2. Milling machine
______b.	A machine that uses a rotating bit to cut a circular hole in a wokrpiece	3. Drill press

Written Test

______ c. A machine that uses abrasive action to remove tiny particles from the surface of a workpiece

______ d. A machine that cuts a workpiece with a rotating tool, then moves the workpiece back into position for the next cut

______ e. A machine that makes straight or circular cuts on a workpiece

______ f. A machine that cuts a workpiece by using tools that move back and forth on the workpiece as the workpiece is advanced

______ g. A machine that cuts a workpiece by rotating the workpiece against the edge of a tool

4. Shaper an planer machine
5. Grinding machine
6. Broaching machine
7. Sawing machine

13. Select true statements about the advantages of numerical control machinery. Place an "X" beside each true statement.

______ a. In general, numerical control permits greater control over the entire manufacturing process.

______ b. High cutting rates save much time.

______ c. The process demands a slightly larger and more diverse inventory.

______ d. Numerical control requires fewer machines and operators, and operator skill requirements aren't as demanding as some.

______ e. The process reduces scrap and rework, and improves product design.

14. Match plastic manufacturing terms with their definitions. Place the number of the term in the blank beside its definition.

______ a. A process where air is blown into heated plastic to force the plastic against the sides of the mold

______ b. The use of pressure and heat to cause material to flow into a mold

1. Extrusion
2. Thermoforming
3. Compression molding

Written Test

______c. The process of forcing plastic through a die of desired shape

______d. The use of heat and pressure to form a single piece from a combination of materials

______e. A process in which plastisol plastic is fused while in a rotating mold

______f. A process of preheating plastic sheets until they are limp, followed by vacuum forming over a mold

______g. Fusing thermoplastic materials together with heat

______h. A process that uses high frequency preheating and plunger to form plastic in a mold cavity

4. Laminating
5. Blow molding
6. Transfer molding
7. Rotational molding
8. Thermoplastic welding

15. Match types of plastics with the methods for their fabrication. Place the number of the plastic type in the blank beside its fabrication method.

______a. Fabricated by machining

______b. Fabricated by forming

______c. Joined by welding

1. Rigid plastic sheet
2. Rigid plastics
3. Flexible thermoplastics

16. Complete statements about guidelines for designing plastic products. Circle the material that best completes each of the following statements.

a. Any wall or rib should be between a minimum of .010″ to (**.130″**) (**.025″**) depending on type of material.

b. Flashing will vary between .002″ and (**.010″**) (**.016″**).

c. Make the draft or taper 25° to (**2°**) (**4°**).

d. Add (**braces**) (**fillets**) to facilitate molding with minimum distortion and breakage.

e. Give ribs and bosses (**5°**) (**7.5°**) tapers.

Written Test

f. Drill or form holes smaller than (**1/16″**) (**1/8″**) in diameter after molding.

17. Match sheet metal processing terms with their definitions. Place the number of the term in the blank beside its definition.

______a. To form corners, edges, and seams in sheet metal

______b. Holes drilled or punched at intersections of bends to relieve strain which would cause metal to crack or buckle

______c. A two-dimensional pattern or shape for sheet metal

______d. Stretching sheet metal over a die in the form of the final product

______e. Using high energy such as explosives or magnetic forming to shape metal

______f. Forming a sheet of metal over a mandrel while the sheet is rotating

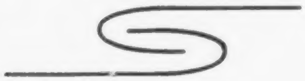
______g. Cutting metal with shears

______h. An overbending operation to allow the material to spring back into a desired shape

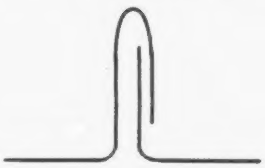
______i. Stretching sheet metal and then forming it with dies

1. Metal spinning
2. Stretch forming
3. High energy forming
4. Shearing
5. Drawing
6. Development
7. Bending
8. Bend relief holes
9. Spring back

18. Identify the following sheet metal hems and joints. Write the name of the hem or joint in the blank below its illustration.

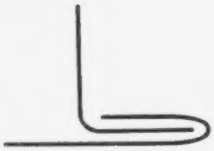


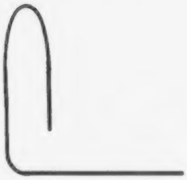
a. ____________________



b. ____________________

Written Test





c. ____________________ d. ____________________

19. Calculate bend allowance for 5 gage thick (.1819) sheet metal when Radius = .5″ and the Number of degrees in the bend are 75°. Use the space provided to show your work; round answer to 3 places.

$BA = (.017453R + .0078T)N$

BA = ____________________

Manufacturing Processes
Unit 8

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Calculate Bend Allowance For Sheet Metal Rating ______

Comments: ______________________________

____

Assignment Sheet 2—Design a Casting Part Rating ______

Comments: ______________________________

____

Assignment Sheet 3—Design a Forging Part Rating ______

Comments: ______________________________

____

Assignment Sheet 4—Design a Welded Part Rating ______

Comments: ______________________________

____

Assignment Sheet 5—Design a Thermoplastic Part Rating ______

Comments: ______________________________

____

Pretest ______ Posttest ______ Other ______

Other ______________________________

____

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

***Permission to duplicate this form is granted.**

Manufacturing Processes
Unit 8

Information Sheet

1. **Terms and definitions**

   a. **Casting** — A metal object formed by pouring molten metal into a mold and then allowing the metal to solidify

   b. **Centrifugal casting** — The process of pouring molten metal into a revolving mold

   c. **Core** — A special body designed to produce a special cavity in or on a casting

   d. **Die casting** — The process of forcing hot metal into a mold or a die

   e. **Forging** — The process of compressing material in a die until it is formed into a new shape

   f. **Investment casting** — The process of pouring a sand mixture, called the investment, around a wax pattern; the casting is made by pouring molten metal into the hardened shell and melting and forcing the wax out

      Note: Investment casting is also known as the "lost wax" process.

   g. **Manufacturing processes** — Processes that remove material from or add material to an original part, or spread material to other areas of a part

   h. **Pattern** — The form used to make a cavity in a sand mold

   i. **Permanent mold casting** — A casting produced with metal molds plus hydrostatic pressure

   j. **Powder metallurgy** — A process that mixes metal powders, compresses them with high pressure and heats them at a high temperature

   k. **Shell molding** — The process of using thin, sand resin shells molded of the pattern; molten metal is poured into the cavity

Information Sheet

2. **Metal treatment processes and their characteristics**

   a. **Chemical machining** — The use of an acid to dissolve metal in areas except where acid resist is used

   b. **Cold working metal** — The forming or plastic deforming of metal while the metal is cold

   c. **Electron beam machining** — A pulsing technique using accelerated electrons that heat and cool an area

   d. **Electro-chemical machining** — The process of removing material from a metal by reversing the electroplating process

   e. **Electronic discharge machining** — The removal of metal with a spark in the presence of a coolant

   f. **Electroplating** — A process of covering metal with electro-deposits of a thin coating of the same or other metal

   g. **Flame spraying** — A process of melting materials and blowing the melted metal onto a surface

   h. **Hot working metal** — Metal in a plastic state formed by mechanical working such as rolling or forging

   i. **Laser machining** — The precise removal of small amounts of metal by using a concentrated focus of intense heat

   j. **Machining operations** — Operations that change the shape, finish, or size by removing material from a workpiece

   k. **Stamping** — Using dies to form or cut metal sheets into a set form

   l. **Ultrasonic machining** — The bombardment of a workpiece with grit driven by linear oscillation of the tool

3. **Production processes and their characteristics**

   a. **Automation** — A numerically controlled (NC) machine or system of machines that control the sequence of operations, tool movement or material movement with little, if any, assistance from an operator

   b. **CNC (Computer Numerical Control) machining** — A numerical control system that uses a special-purpose computer to operate machine tools

Information Sheet

c. **Extrusion** — The process of pushing or forcing metal through a shaped-formed die

d. **Fusion** — The process of melting materials or melting materials together

e. **Injection molding** — The process of ramming hot plastic into a mold to form a shape

f. **NC (Numerical Control) machining** — Operation of machine tools with automatic programmed cutting sequences using direct information or numerical data stored on paper, magnetic other media to produce accurate machining of complex geometrical surfaces

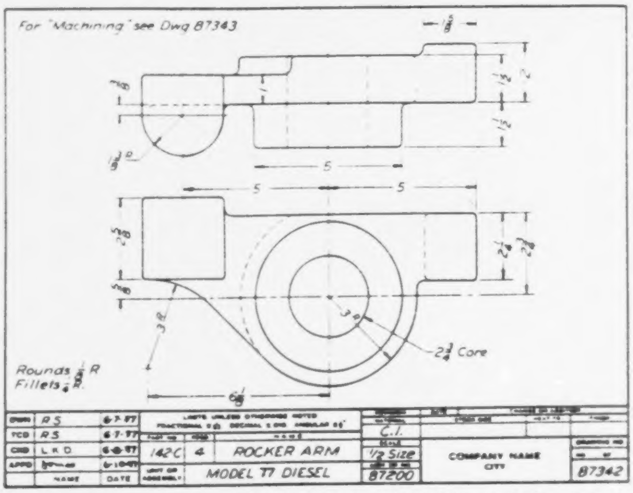
g. **Surface preparation** — A mechanical or chemical process used to improve the resistance to wear, surface hardness, coatability, or appearance of a part

h. **Transfer machine** — A machine that has the capability to transfer a workpiece from one operation to another operation in the same machine or to a different machine

Note: Transfer machines permit the maximum number of production operations that can be performed on workpieces to achieve a maximum production rate.

4. Principal types of drawing for manufacturing processes

a. Casting


For "Machining" see Dwg 87343
Rounds 1/8 R
Fillets 1/4 R.
2 3/4 Core
3 R
5
6 1/8
ROCKER ARM
MODEL T7 DIESEL
142C
4
C.I.
1/2 Size
87200
COMPANY NAME
CITY
87342
RS
RS
L.K.D.

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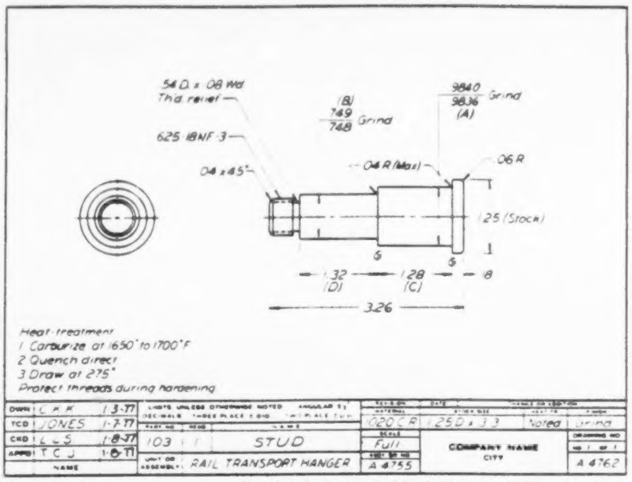
Information Sheet

b. Machining


54 D x 08 Wd
Thd relief
625 18NF-3
04 x 45°
(B)
749
748 Grind
9840
9836 Grind
(A)
04 R (Max)
06 R
125 (Stock)
1.32
(D)
1.28
(C)
18
3.26
Heat-treatment
1 Carburize at 1650° to 1700°F
2 Quench direct
3 Draw at 275°
Protect threads during hardening
C H K 1-3-77
JONES 1-7-77
L L S 1-8-77
T C J 1-8-77
NAME
103
STUD
RAIL TRANSPORT HANGER
1020 C R
1.25 D x 3.3
Noted
Grind
Full
A 4755
COMPANY NAME
CITY
A 4762

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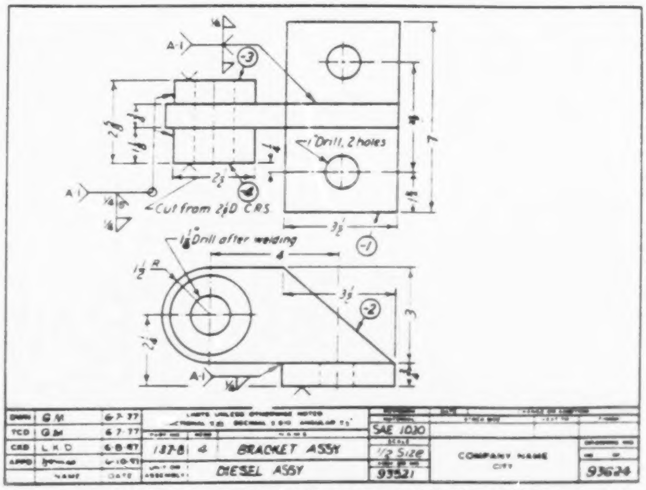
c. Welding


A-1
1/4
-3
-4
-1
-2
2 7/8
1 1/8
1" Drill, 2 holes
Cut from 2 1/2 D CRS
2 1/2
3 1/2
7
1 1/2 Drill after welding
4
1 1/2 R
3 1/2
3
2 1/4
G M 6-7-77
G M 6-7-77
L K D 6-8-77
NAME
DATE
137-8
4
BRACKET ASSY
DIESEL ASSY
SAE 1020
1/2 Size
93521
COMPANY NAME
CITY
93624

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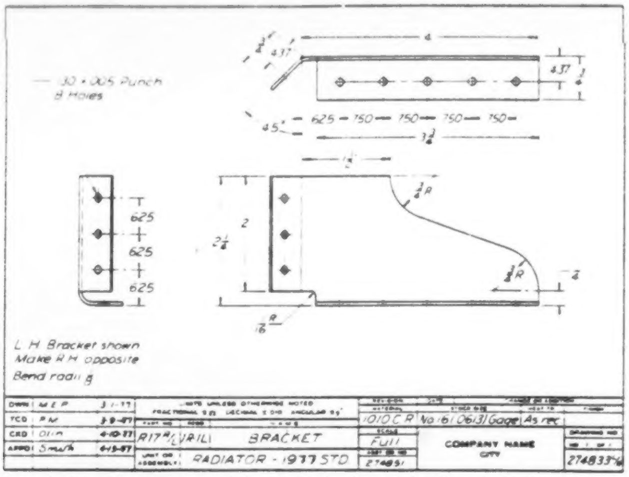
Information Sheet

d. Sheet metal


.30 ± .005 Punch
8 Holes
.437
4
45°
.625
.750
3 1/4
1 1/2
3/4 R
2
2 1/4
.625
3/8 R
1/16 R
L.H. Bracket shown
Make R.H. opposite
Bend radii 1/8
BRACKET
RADIATOR - 1977 STD
Full
COMPANY NAME
CITY
274833

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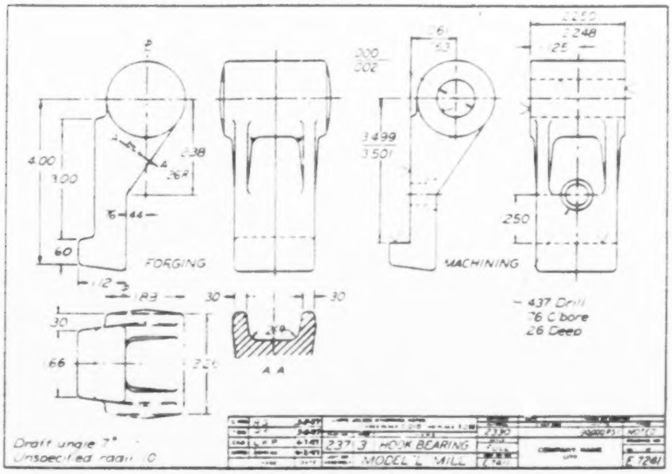
e. Forging


4.00
3.00
.60
2.38
.26R
FORGING
3.499
3.501
.250
MACHINING
2.250
2.248
.25
.30
.66
.183
A-A
.437 Drill
.76 C'bore
.26 Deep
Draft angle 7°
Unspecified radii .10
HOOK BEARING
MODEL "L" MILL
COMPANY NAME
E 7241

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Information Sheet

5. **Casting terms and their definitions**

   a. **Alignment pins** — Devices to align the drag and cope of a flask

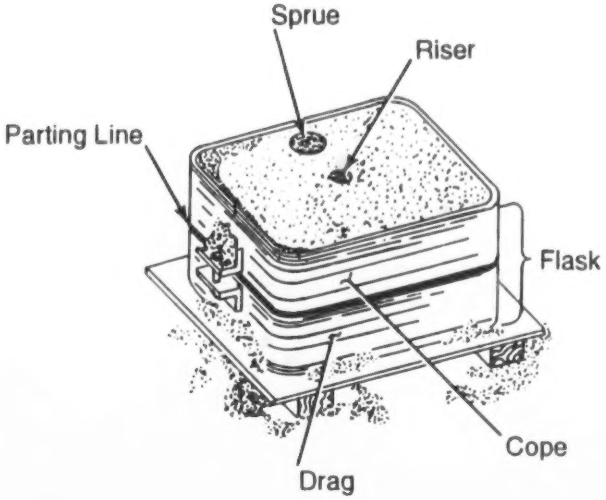
   b. **Cheek** — The middle part of the flask

   c. **Cope** — The top half of the flask

   d. **Draft** — The pattern taper for easy removal of a pattern from a mold

   e. **Drag** — The bottom half of the flask

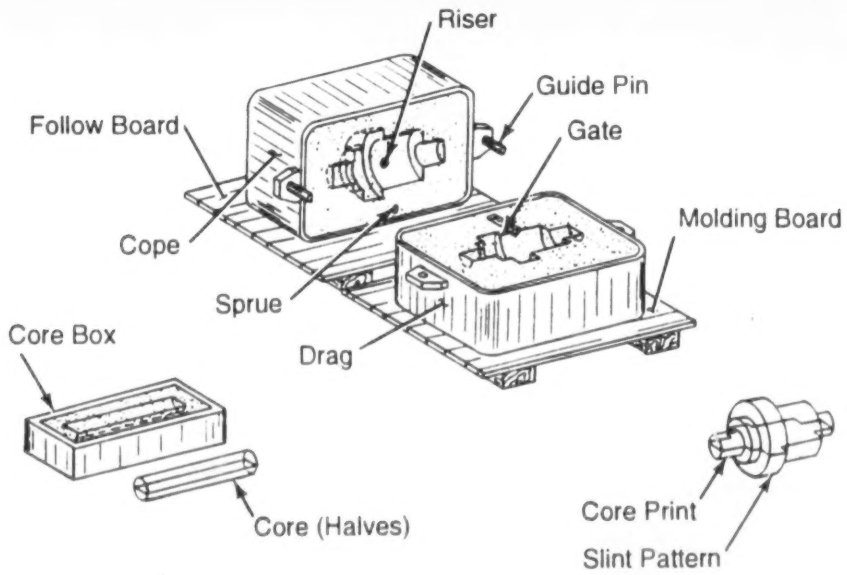
   f. **Flask** — The complete mold



   g. **Gate** — Opening for molten metal to flow between the sprue and the mold cavity

Information Sheet

h. **Parting line** — The line where the mold separates

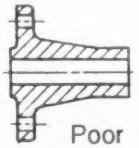

Riser
Guide Pin
Follow Board
Gate
Molding Board
Cope
Sprue
Core Box
Drag
Core (Halves)
Core Print
Slint Pattern

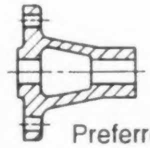
i. **Riser** — Relief that permits air and molten metal to rise

j. **Sprue** — The tapered hole in the cope of a casting mold through which molten metal is poured into the mold cavity

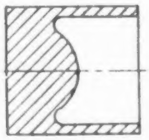
6. Guidelines for designing a casting

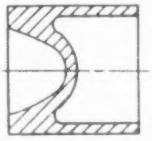
a. Avoid abrupt changes in a section.


Poor


Preferred

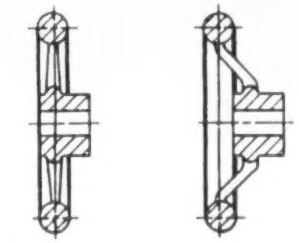
b. Keep the wall thickness of sections uniform.


Poor


Preferred

Information Sheet

c. Avoid creating internal stress.

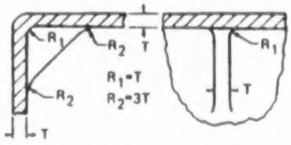


Often Done Preferred

d. Use a minimum number of adjoining sections.

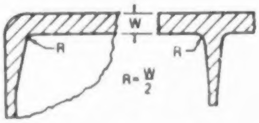
Note: See the graphic in item g, this objective.

e. Make fillet radii equal to rib thickness.



Preferred

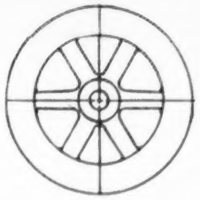
f. Thicken thin members when the approach a thick member.



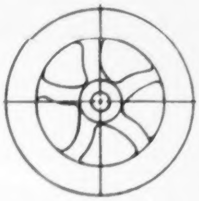
Preferred

Information Sheet

g. Prevent stresses along spokes by designing with odd number instead of even number of spokes.

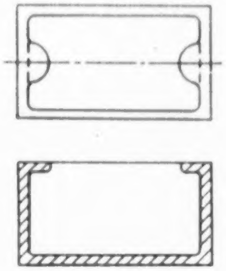


Often Done

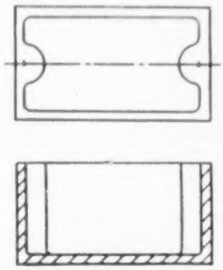


Preferred

h. Allow room for withdrawing the pattern from the sand after casting.



Poor



Preferred

i. Use a shrink rule to lay out patterns.

Note: Materials have different shrinkage factors so different shrink rules are available. A cast iron shrinkage rule is 1/8″ longer per foot than a standard rule, and an aluminum shrinkage rules is 5/32″ longer per foot than a standard rule.

j. Add a draft or taper to the pattern to allow the casting to be removed from the mold.

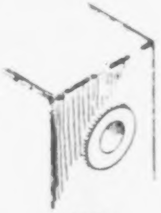
k. Provide extra metal or a finish allowance so the metal can be machined after casting.

Note: For average castings, a finish allowance is usually 1/8″, 3.2mm.

Information Sheet

l. Use a boss, a cylindrical projection on the casting, to give a bearing surface to which a fastener can be attached.

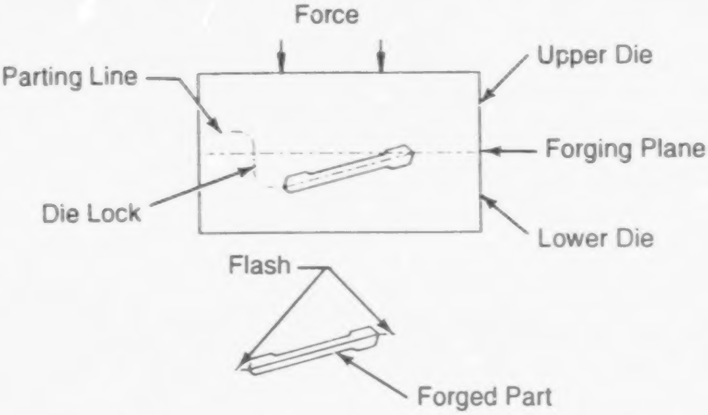
Note: A boss requires less machining.



7. **Forging terms and their definitions**

a. **Die** — Device used in shaping or stamping an object or flat material

b. **Die closure** — The amount added to a die when dies do not close



c. **Draft** — Taper of surfaces to allow easy removal from the die

d. **Flash** — The slight excess that appears as a thin fin of material surrounding a forging at the parting line

e. **Match tolerance** — Measurement of the displacement of two opposing dies in the direction parallel to the parting line of the dies

f. **Parting line** — The line where dies meet and separate; also called a flash line

g. **Forging plane** — The plane perpendicular to the direction of pressure

Information Sheet

8. Guidelines for designing a forging

a. Avoid sharp corner fillets except when material is flowing away; fillets may be sharper.

b. Design a large fillet if material is flowing toward the fillet.

c. Use strippers and ejectors when little or no draft is used.

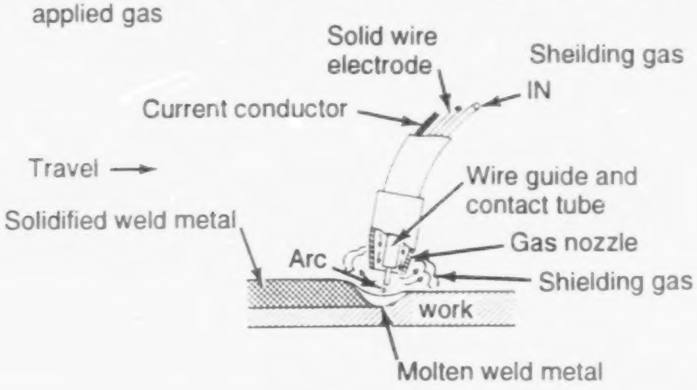
d. Make the dies last longer by allowing generous tolerances for dies in areas of greatest pressure and flow.

9. Welding terms and their definitions

a. **Destructive testing** — A method of testing welded samples by bending, breaking, or otherwise destroying the usefulness of the tested material

b. **Forge welding** — A process where heated metals are forced together under pressure

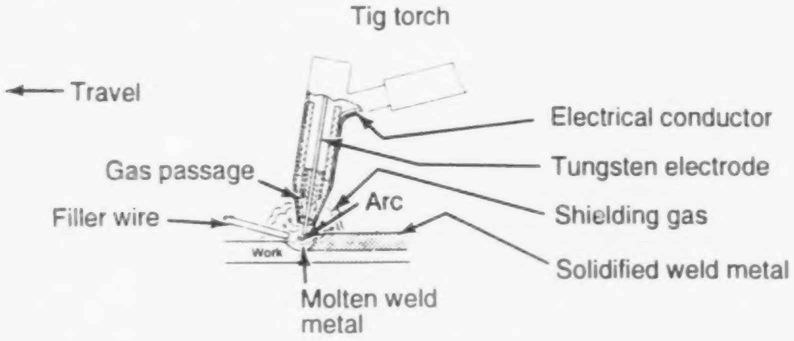
c. **Gas metal arc welding (GMAW)** — An arc welding process that produces coalescence of metals by heating them with an arc between a continuous filler metal electrode and a workpiece; shielding is obtained entirely from an externally applied gas


Solid wire electrode
Sheilding gas
IN
Current conductor
Travel →
Wire guide and contact tube
Solidified weld metal
Arc
Gas nozzle
Shielding gas
work
Molten weld metal

Courtesy Lincoln Electric Company

Information Sheet

d. **Gas tungsten arc welding (GTAW)** — An arc welding process that produces coalescence of materials by heating them with an arc between a nonconsumable tungsten electrode and a workpiece; shielding is obtained from a gas, and filler metal may or may not be used

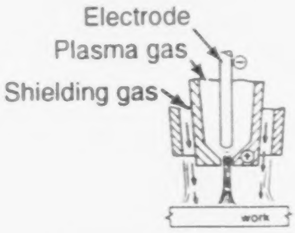

Tig torch
Travel
Electrical conductor
Tungsten electrode
Gas passage
Arc
Shielding gas
Filler wire
Work
Solidified weld metal
Molten weld metal

Courtesy Lincoln Electric Company

e. **Induction welding** — A process where electric current is used to heat and metal parts so that the parts fuse together; an economical high production welding process

f. **Nondestructive testing** — A method of testing welded materials with X-rays, magnetic particles, or even visually so that the usefulness of the material is not destroyed

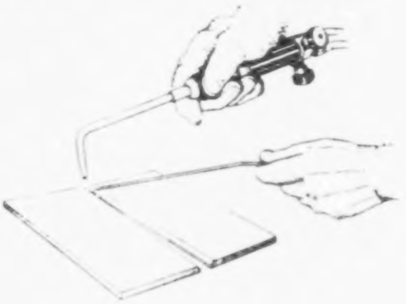
g. **Plasma arc welding (PAC)** — An arc welding process that produces coalescence of metals by heating them with a constricted arc between a nonconsumable electrode and a workpiece, or the electrode and a constricting nozzle


Electrode
Plasma gas
Shielding gas
work

Courtesy Lincoln Electric Company

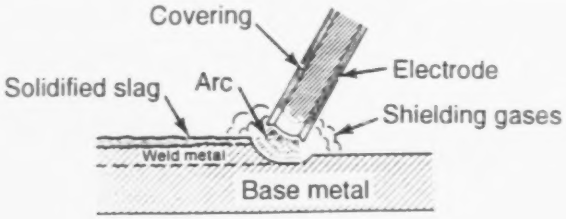
Information Sheet

h. **Oxyfuel gas welding (OFW)** — A group of welding processes that produce coalescence by heating materials with an oxyfuel gas flame or flames, with or without pressure, and with or without filler metal



i. **Resistance welding** — The process of placing parts together, then passing a heavy current through them to make the metals melt and fuse together

j. **Shielded metal arc welding (SMAW)** — An arc welding process that produces coalescence of materials by heating them with an arc between a covered electrode and a workpiece; shielding is obtained from decomposition of the electrode cover, and filler metal is obtained from the electrode



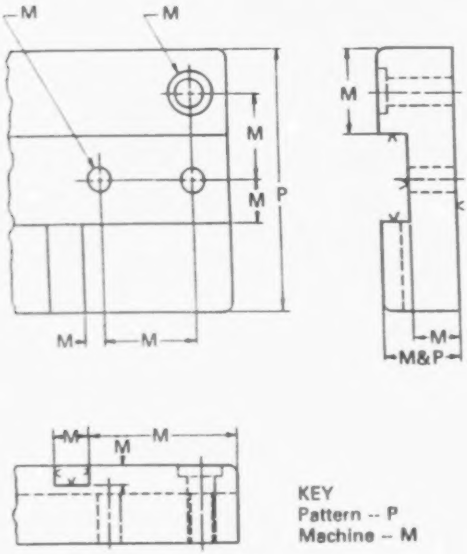
Courtesy Lincoln Electric Company

k. **Thermit welding** — A process that weld metals together as a result of the chemical reaction between powdered aluminum and powdered metal oxide

Information Sheet

10. Pattern and machine dimensions and their applications

a. Pattern dimensions are needed only by a pattern maker to make a pattern.



b. Machine dimensions are needed only by a machinist to make a part.

11. Guidelines for designing a welded assembly

a. Use standard rolled shapes such as I beams, channels, zees, and tees.

b. Design for calculated load to avoid wasting materials.

c. Use deep sections to avoid bending.

d. Choose stiffeners properly to provide rigidity with less weight.

e. Use closed sections or diagonal bracing to control torsion (twisting).

f. Provide suitable access for maintenance.

g. Design with minimum number of pieces.

h. Eliminate beveling if a deep penetrating arc can be used.

i. Use a minimum root opening to avoid the need for excess filler metal.

j. Place welds on the shortest seams.

Information Sheet

12. **Types of machines and their uses**

    a. **Broaching machine** — A machine that pulls or pushes a broaching tool over a workpiece surface to machine simple or complex contours

    Note: Broaching eliminates the need for highly skilled machine operators, and is one of the most productive precision machining processes because it holds small tolerances and produces precision finishes.

    b. **Drill press** — A machine that uses a rotating bit to cut a circular hole in a workpiece

    c. **Grinding machine** — A machine that uses abrasive action

    d. **Milling machine** — A machine that cuts a workpiece with a rotating tool, then moves the workpiece back into position for the next cut

    e. **Sawing machine** — A machine that makes straight or circular cuts on a workpiece

    f. **Shaper and planer machine** — A machine that cuts a workpiece by using tools that move back and forth on the workpiece as the workpiece is advanced

    g. **Lath** — A machine that cuts a workpiece by rotating the workpiece against the edge of a tool

13. **Advantages of numerical control machinery**

    a. In general, numerical control permits greater control over the entire manufacturing process.

    b. High cutting rates save much time.

    c. The process helps reduce inventory.

    d. Numerical control requires fewer machines and operators, and operator skill requirements aren't as demanding as some.

    e. The process reduces scrap and rework, and improves product design.

14. **Plastic manufacturing terms and their definitions.**

    a. **Blow molding** — A process where air is blown into heated plastic to force the plastic against the sides of the mold

    b. **Compression molding** — The use of pressure and heat to cause material to flow into a mold

Information Sheet

c. **Extrusion** — The process of forcing plastic through a die of a desired shape

d. **Laminating** — The use of heat and pressure to form a single piece from a combination of materials

e. **Rotational molding** — A process in which plastisol plastic is fused while in a rotating mold

f. **Thermoforming** — A process of preheating plastic sheets until they are limp, followed by vacuum forming over a mold

g. **Thermoplastic welding** — Fusing thermoplastic materials together with heat

h. **Transfer molding** — A process that uses high frequency preheating and a plunger to form plastic in a mold cavity

15. **Types of plastics and methods for their fabrication**

a. **Rigid plastics** — Fabricated by machining

b. **Flexible thermoplastics** — Fabricated by forming

c. **Rigid plastic sheet** — Joined by welding

16. **Guidelines for designing plastic products**

a. Any wall or rib should be between a minimum of .010" (.2mm) to .130" (3.2mm) depending on type of material.

b. Flashing will vary between .002" (.05mm) and .016" (.40mm).

c. Make the draft or taper .25° to 4°.

d. Add fillets to facilitate molding with minimum distortion and breakage.

e. Give ribs and bosses 5° tapers.

f. Drill or form holes smaller than 1/16" in diameter after molding.

Note: There are many more good guidelines for designing plastic products. Consult specific reference books for other details.

Information Sheet

17. **Sheet metal processing terms and their definitions.**

a. **Bending** — To form corners, edges, and seams in sheet metal

b. **Bend relief holes** — Holes drilled or punched at intersections of bends to relieve strain which would cause metal to crack or buckle

c. **Development** — A two-dimensional pattern or shape for sheet metal

d. **Drawing** — Stretching sheet metal over a die in the form of the final product

e. **High energy forming** — Using high energy such as explosives or magnetic forming to shape metal

f. **Metal spinning** — Forming a sheet of metal over a mandrel while the sheet is rotating

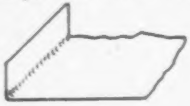
g. **Shearing** — Cutting metal with shears

h. **Spring back** — An overbending operation to allow the material to spring back into a desired shape

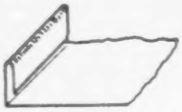
i. **Stretch forming** — Stretching sheet metal and then forming it with dies

18. **Sheet metal hems and joints and their shapes**

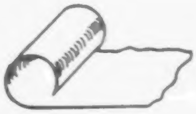
a. Single flange



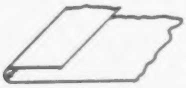
b. Double flange



c. Rolled flange

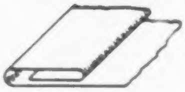


d. Single hem

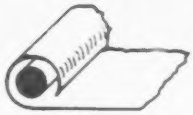


Information Sheet

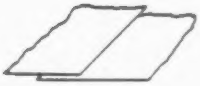
e. Double hem



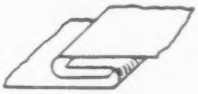
f. Wired edge



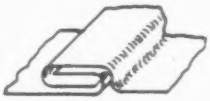
g. Lap seam



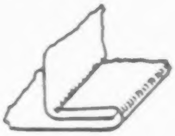
h. Plain flat seam



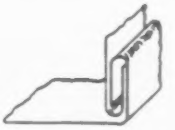
i. Grooved seam



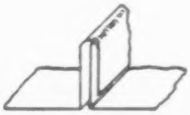
j. Single seam



k. Double seam



l. Standing seam



19. Guidelines for calculating sheet metal bend allowance

a. BA = Bend allowance = $(.017453R + .0078T)N$

b. R = Radius of the bend

c. T =- Metal thickness

d. N = Number of degrees in the bend

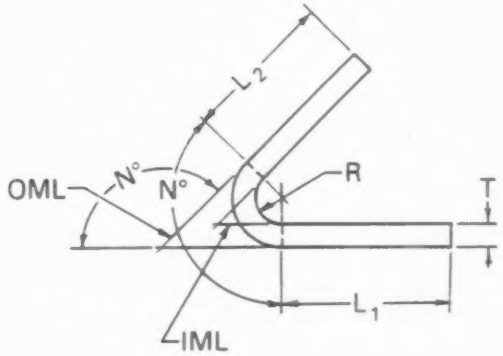
Information Sheet

e. L (Length) = $L_1 + L_2 + BA$

f. OML = Outside mold line

g. IML = Inside mold line

Note: Bend allowance tables have been tabulated for many industries based on experimental data and proven methods. Bend allowance depends on many variables: type of material, thickness, degree of bend, bend radius, bending process, surface condition, surface lubrication, and the grain of the material.



Manufacturing Processes
Unit 8

Assignment Sheet 1—Calculate Bend Allowance For Sheet Metal

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Number of problems attempted	______
Number of problems correctly calculated	______

Directions: Calculate bend allowance for the following problems using the formula: BA = (.017453R + .0078T)N, and round your answer to 3 places.

CAD Alert: The bend allowance formula can be programmed and executed on most CAD systems using AUTOLISP, Pascal, or "C", and executed on demand. Some hand-held calculators can also be programmed in BASIC to calculate BA.

Problems:

A. Radius: .531″
Thickness: .025″
Number of degrees in bend: 90°

BA = ____________

B. Radius: .438″
Thickness: .25″
Number of degrees in bend: 120°

BA = ____________

C. Radius: .094″
Thickness: .094″
Number of degrees in bend: 90°

BA = ____________

D. Radius: .25″
Thickness: .125″
Number of degrees in bend: 85°

BA = ____________

E. Radius: .031″
Thickness: .038″
Number of degrees in bend: 30°

BA = ____________

F. Radius: .219″
Thickness: .025″
Number of degrees in bend: 120°

BA = ____________

Manufacturing Processes
Unit 8

Assignment Sheet 2—Design a Casting Part

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Quality of casting design	______
Dimensions and notes for pattern maker	______
Neatness and appearance	______

Directions: Select a workpiece from the ones included with this assignment sheet, or have your instructor select a workpiece for you. Redesign the workpiece into a casting drawn on a CAD system or on a drawing table using proper instruments. Include all dimensions and notes for a pattern maker.

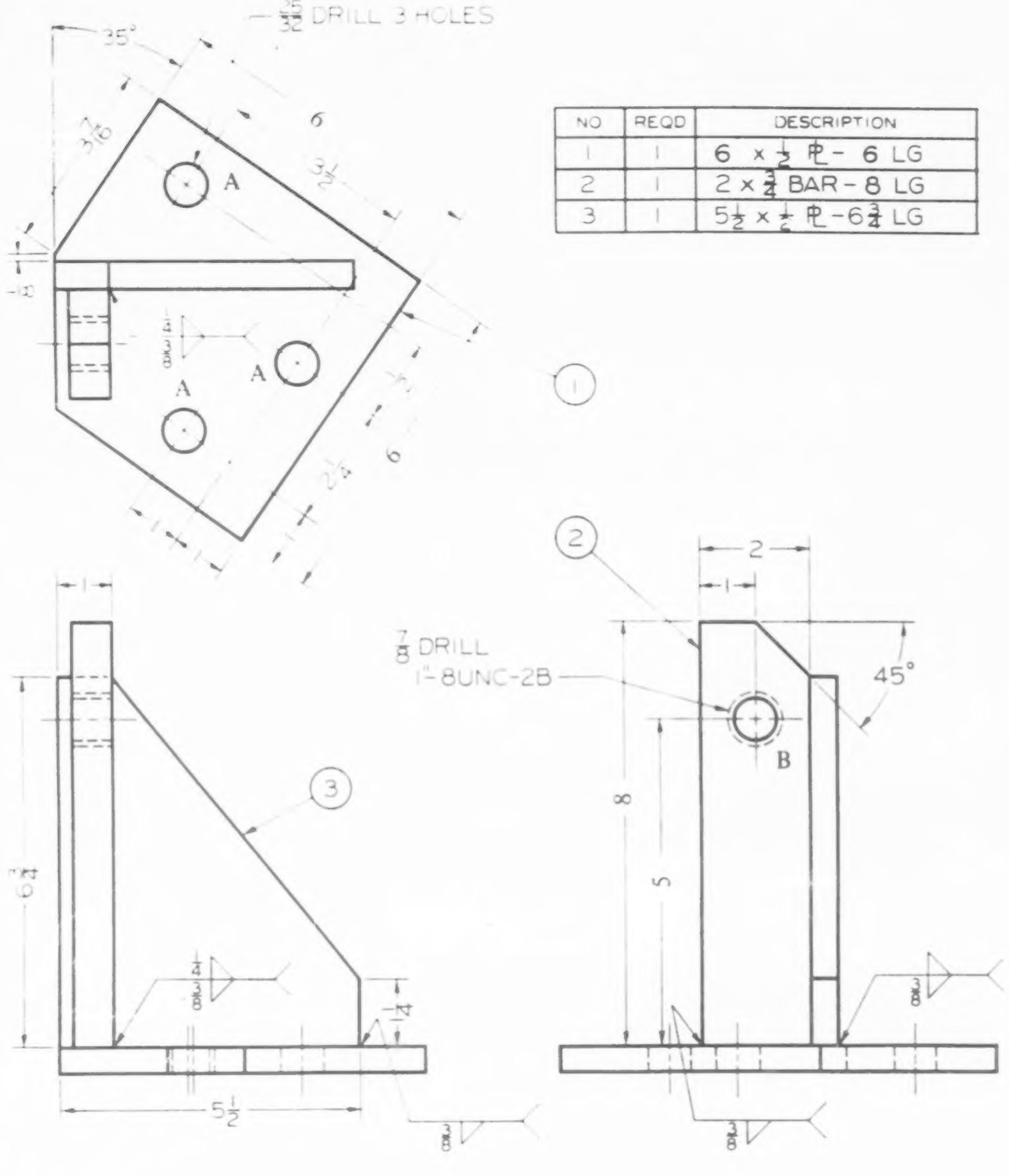
CAD Alert: Use your CAD system to redesign the workpiece and solve your design problems for your casting part.

Problems:

A. Include the following changes:

   1. 1/8" high by 1 1/4" DIA boss on holes "A"
   2. Finish "V" bottom surface, bosses, and left side
   3. Fillets and rounds 1/8" radius
   4. Add 1/4" high by 1 1/2" DIA boss to front and back of hole "B"
   5. Finish boss surfaces

Assignment Sheet 2



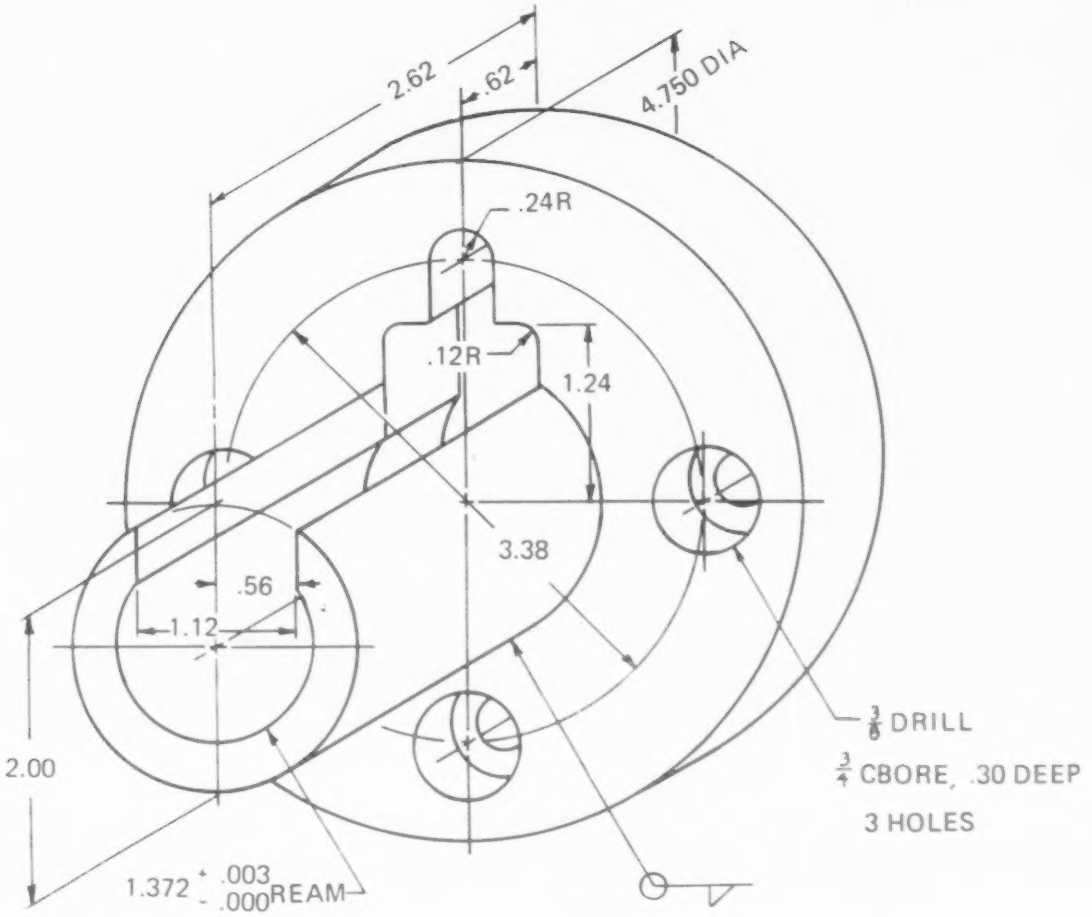
NO	REQD	DESCRIPTION
1	1	6 × $\frac{1}{2}$ PL − 6 LG
2	1	2 × $\frac{3}{4}$ BAR − 8 LG
3	1	$5\frac{1}{2}$ × $\frac{1}{2}$ PL − $6\frac{3}{4}$ LG

25/32 DRILL 3 HOLES
35°
3 7/16
6
3 1/2
1/8
A
A
A
3/8
1/4
①
3 1/2
6
2 1/4
1
1
②
2
1
7/8 DRILL
1"-8UNC-2B
B
45°
8
5
③
6 3/4
1/4
3/8
1 1/4
5 1/2
3/8
3/8
3/8

Assignment Sheet 2

B. Include the following changes:

1. Finish front and back surfaces
2. Use 1/4″ radius for rounds
3. Use 3/8″ radius for fillets


2.62
.62
4.750 DIA
.24R
.12R
1.24
3.38
.56
1.12
2.00
1.372 + .003 - .000 REAM
3/8 DRILL
3/4 CBORE, .30 DEEP
3 HOLES

CENTERING BUSHING

Manufacturing Processes
Unit 8

Assignment Sheet 3—Design a Forging Part

Name ______________________________ Overall Rating __________

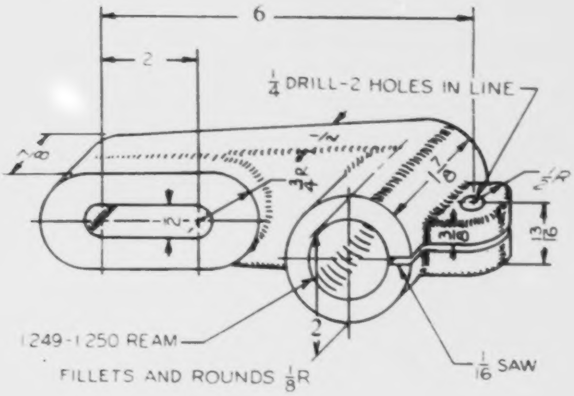
Evaluation criteria	**Rating**
Quality of forging design	______
Dimensions and notes for a forging design	______
Bearing surfaces and draft angles	______
Neatness and appearance	______

Directions: Select a workpiece from the ones included with this assignment sheet, or have your instructor select a workpiece for you. Redesign the workpiece into a forging drawn on a CAD system or on a drawing table using proper instruments. Redesign the shape, if necessary, but hold all bearing surfaces true, and make all draft angles 7°. Include all dimensions and notes necessary for a forging design.

CAD Alert: Use your CAD system to redesign the workpiece and solve your design problems for your forging part.

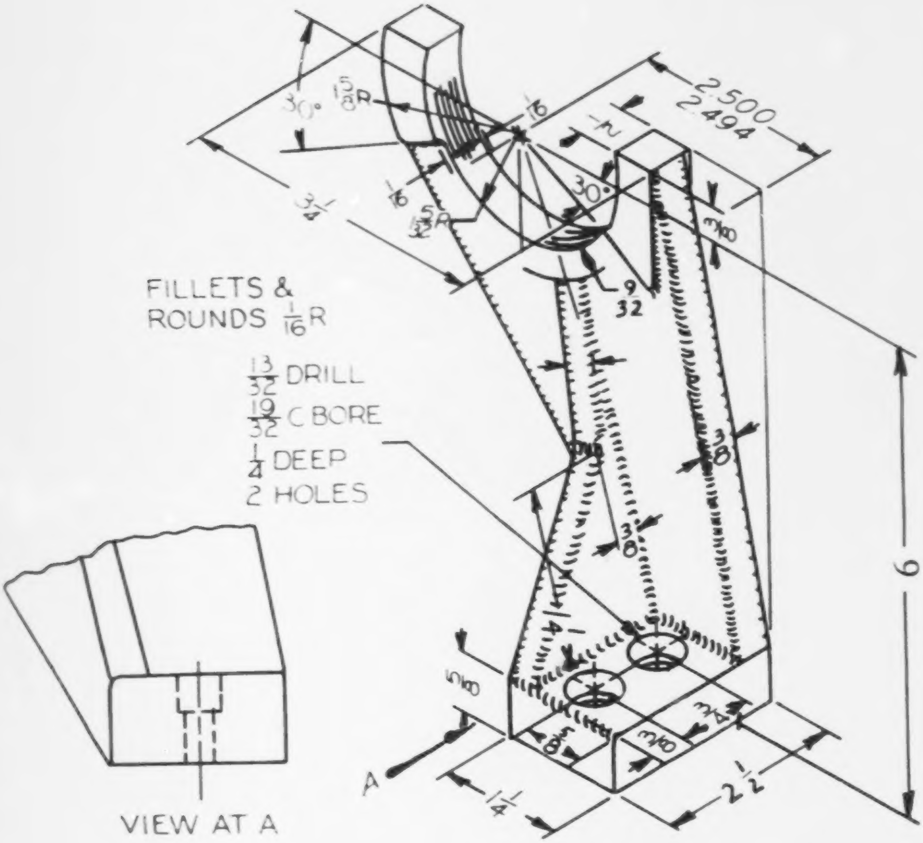
Problems:

A.


6
2
1/4 DRILL-2 HOLES IN LINE
7/8
1/2
3/4 R
1 7/8
1/2
5/8 R
13/16
3/8
2
1.249-1.250 REAM
FILLETS AND ROUNDS 1/8 R
1/16 SAW

Assignment Sheet 3

B.


30°
1 5/8 R
1/16
2.500
2.494
1/2
30°
3 1/4
1/16
15/32 R
3/8
9/32
FILLETS & ROUNDS 1/16 R
13/32 DRILL
19/32 C BORE
1/4 DEEP
2 HOLES
1
3/8
3/8
1/4
6
5/8
5/8
3/8
3/4
1 1/4
2 1/2
A
VIEW AT A

Manufacturing Processes
Unit 8

Assignment Sheet 4—Design a Welded Part

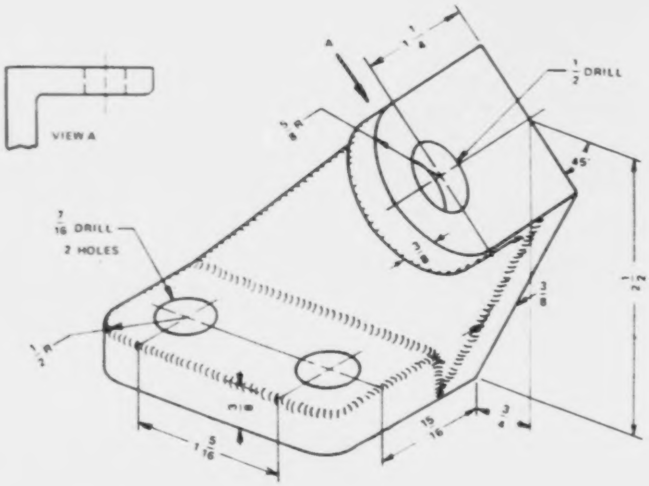
Name ______________________________ Overall Rating __________

Evaluation criteria	Rating
Parts list of raw stock correct and complete	______
Dimensions and notes for a welding design	______
Use of proper welding symbols	______
Neatness and appearance	______

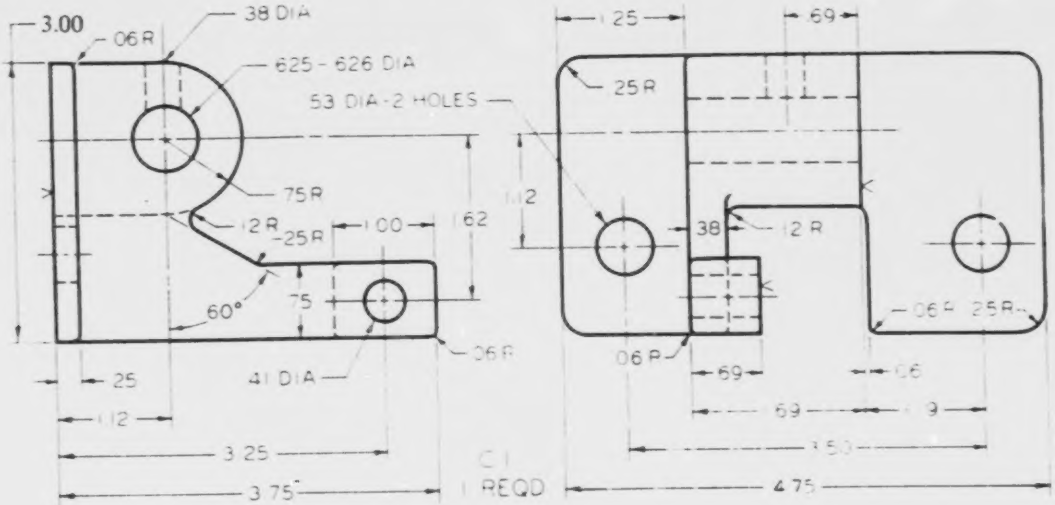
Directions: Select a workpiece from the ones included with this assignment sheet, or have your instructor select a workpiece for you. Redesign the workpiece into a welded assembly on a CAD system or on a drawing table using proper instruments. Include all dimensions, symbols, and notes for the welded assembly, and include a parts list of raw stock.

CAD Alert: Use your CAD system to redesign the workpiece and solve your design problems for your welded part.

Problems: A



Assignment Sheet 4


3.00
.06 R
.38 DIA
.625 - .626 DIA
.53 DIA - 2 HOLES
.75 R
.12 R
.25 R
1.00
1.62
.75
60°
.41 DIA
.06 R
.25
1.12
3.25
3.75
C.I.
1 REQD
1.25
.69
.25 R
1.12
.38
.12 R
.06 R
.25 R
.06 R
.69
.06
.69
1.9
3.50
4.75

BRACKET BEARING

Manufacturing Processes
Unit 8

Assignment Sheet 5—Design a Thermoplastic Part

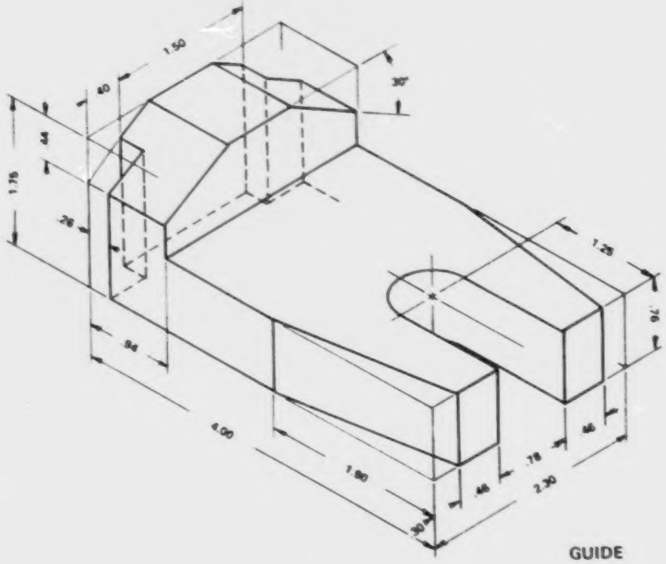
Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Parts attached to common core	______
Dimensions and notes for a thermoplastic design	______
Neatness and appearance	______

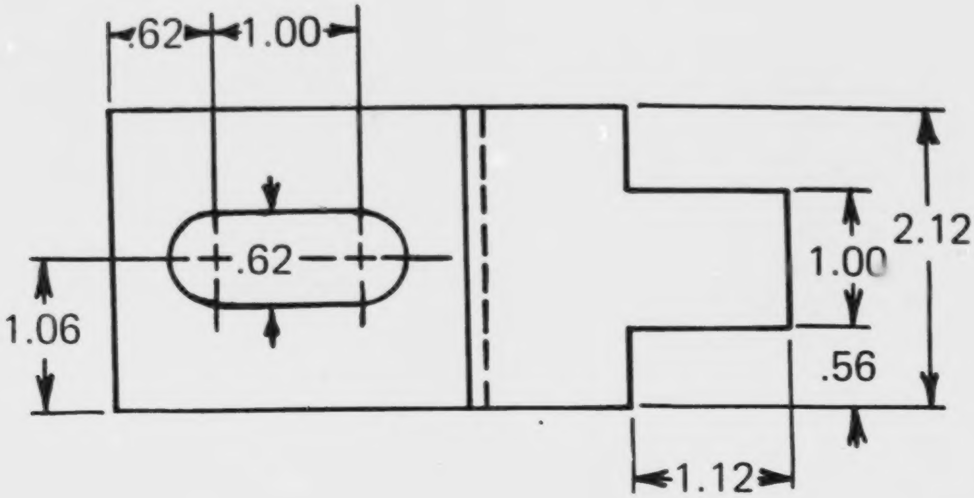
Directions: Select a workpiece as presented in this assignment sheet or a workpiece selected by your instructor. Use a CAD system or a drawing table and proper instruments to design a thermoplastic part which will be injection molded. Draw four parts attached to a common core, for these will be the parts that are injection molded. Include necessary sizes and dimensions.

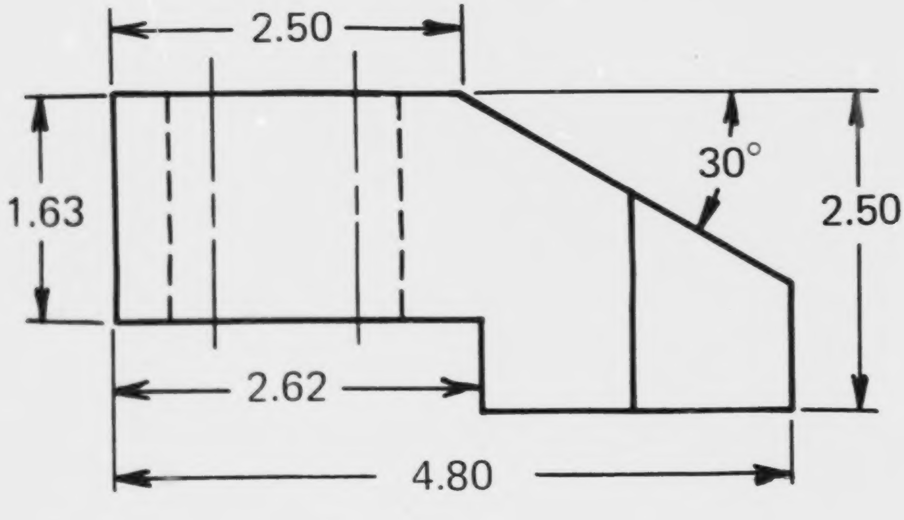
> **CAD Alert:** Use your CAD system to design the thermoplastic part, and use mirror copy to produce the four parts attached to a common core.

Problems: A



Assignment Sheet 5


.62
1.00
.62
1.06
1.00
2.12
.56
1.12


2.50
1.63
30°
2.50
2.62
4.80

Sheet Metal Developments
Unit 9

Objective Sheet

Unit Objective

After completing this unit, the student should be able to construct true lengths of lines and planes, construct true lengths of lines and planes by rotation, construct intersection of surfaces using edge views and by the two-view method, and construct radial line developments, parallel line developments, and triangulation developments. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to sheet metal developments with their correct definitions.
2. Match surface conditions with their characteristics.
3. Complete statements about guidelines for visualization of near points and planes.
4. Complete statements about guidelines for visualization of far points and planes.
5. Complete statements about guidelines for observing planes.
6. Complete statements about guidelines for labeling points, lines, and planes.
7. Arrange in order the steps for constructing an auxiliary view.
8. Identify true length lines and true size planes.
9. Identify point views of lines and edge views of planes.
10. Select true statements about rotation characteristics.

Objective Sheet

11. Select elements of single curved surfaces.

12. List methods for finding intersections of surfaces.

13. Match general groups of sheet metal developments with their characteristics.

14. Calculate a bend allowance.

15. Label points, lines, and planes in views. (Assignment Sheet 1)

16. Identify true lengths and types of lines. (Assignment Sheet 2)

17. Identify true sizes and types of planes. (Assignment Sheet 3)

18. Construct true length lines and true length planes using auxiliary views. (Assignment Sheet 4)

19. Construct true length of lines by rotation. (Assignment Sheet 5)

20. Construct true sizes of planes by rotation. (Assignment Sheet 6)

21. Locate elements of single curved surfaces. (Assignment Sheet 7)

22. Construct intersections of surfaces. (Assignment Sheet 8)

23. Construct intersections of surfaces using the two-view method. (Assignment Sheet 9)

24. Construct radial line developments. (Assignment Sheet 10)

25. Construct parallel line developments. (Assignment Sheet 11)

26. Construct special developments using triangulation. (Assignment Sheet 12)

Sheet Metal Developments
Unit 9

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for enrichment of exceptional students as well as accommodation of special needs students.

4. Make transparencies from the transparency masters included with this unit. These appear in the teacher edition only and are designed to be used with the following objectives:

   TM 1—Labeling Points, Lines, and Planes (Objective 6)
   TM 2—Steps for Constructing Auxiliary Views (Objective 7)
   TM 3—True Length of Lines (Objective 8)
   TM 4—Identifying True Lengths (Objective 8)
   TM 5—observing True Size Planes (Objective 8)
   TM 6—Identifying True Sizes (Objective 8)
   TM 7—Edge Views of Planes (Objective 9)
   TM 8—Rotation of a Point (Objective 10)
   TM 9—True Lengths by Rotation (Objective 10)
   TM 10—True Sizes by Rotation (Objective 10)
   TM 11—Elements of Single Curved Surfaces (Objective 11)
   TM 12—Intersections with Edge View Given (Objective 12)
   TM 13—intersections Using Auxiliary Views (Objective 12)
   TM 14—Developments (Objective 13)
   TM 15—Radial Line Developments Pyramids (Objective 13)
   TM 16—Radial Line Developments Cones (Objective 13)
   TM 17—Parallel Line Developments Prisms (Objective 13)
   TM 18—Parallel Line Developments Cylinders (Objective 13)
   TM 19—Triangulation (Objective 13)

5. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.

6. Develop teaching plan. Adjust for different learning styles.

7. Make copies of unit evaluation form.

Suggested Activities

Delivery and Application

8. Provide students with unit of instruction.

9. Discuss unit and specific objectives.

10. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic academic and workplace skills when applicable.

11. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Evaluation

12. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

13. Make copies of the written test. Add or modify test questions as needed.

14. Give written test.

15. Compile assignment sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignments.

16. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Review the unit carefully. It is a long unit and will require extra time to teach. Break the unit into parts that will be easy for students to work with. Plan to administer the test in at least two parts. Review the assignment sheets and allow plenty of time for students to complete them. There is a great deal of drawing required in almost all of the assignment sheets, and Assignment Sheets 10, 11, and 12 should permit the student to complete a drawing at a CAD workstation. Skill area: **Learning skills, learning to learn.**.

2. Starting with Objective 6, use your transparency masters as overheads to help students visualize some of the complex activities involved with working with lines and planes. Skill area: **Foundation skills, reading and science.**

Suggested Activities

3. Starting with Objective 13, once again use your transparency masters as overheads to help students grasp the fundamentals of radial and parallel line developments. These activities are the heart of sheet metal developments and require special attention. Take your time with the objective, and be sure to demonstrate the procedures on a CAD system so student will be properly prepared for the assignment sheet s that conclude the unit. Skill area: **Foundation skills, math and science.**

4. After students have demonstrated acceptable drafting skills on a board or on a CAD system, use a third-party unfolding software package on the CAD system to demonstrate automated developments.

Resources Used in Developing This Unit

1. Giesecke, Frederick E. *Technical Drawing.* New York: Macmillan Publishing Company, 1992.

2. Pare, E., et. al. *Descriptive Geometry Metric.* 5th Ed. New York: Macmillan Publishing Co., 19??

3. Earle, James H. *Descriptive Geometry.* 2nd Ed. Reading, MA: Addison-Wesley Publishing Co., 1976.

4. Staby, Steve M. *Fundamentals of Three Dimensional Descriptive Geometry.* 2nd Ed. New York: John Wiley and Sons, Inc., 1982

5. Jones, Leonard, and Otto Morse. *Basic Sheet Metal Layout and Fabrication.* Stillwater, OK: The Mid-American Vocational Curriculum Consortium, 1984.

6. Jones, Leonard, and Otto Morse. *Advanced Sheet Metal Layout and Fabrication.* Stillwater, OK: The Mid-America Vocational Curriculum, 1984.

Suggested Supplemental Resource

Profold is flat pattern development software that works with both CADKEY and AutoCAD. For a free demonstration program, call 513-831-8800 or write:

Applied Production, Inc.
200 TechneCenter Drive, Suite 202
Milford, OH 45150

Sheet Metal Developments
Unit 9

Answers to Assignment Sheets

Assignment Sheet 1

The labeling of all problems should be evaluated to the satisfaction of the instructor.

A. 1. 12
   2. abcdef

B. 1. yzvj, abcdef, klmnop, ghdc
   2. Yes
   3. Normal
   4. Inclined

C. D Evaluated to the satisfaction of the instructor

Assignment Sheet 2

A.

LINE	VIEW TL IS LOCATED	NON-TL	TYPE OF LINE		
			NORMAL	INCLINED	OBLIQUE
ab	Top & Side	—	X		
cd	Top & Side	—	X		
hc	Front	Top & Side		X	
ef	Side	Front & Top		X	
nf	Top & Front	—	X		
oj	Front & Side	—	X		
gf	Top & Side	—	X		
hi	Top & Side	—	X		
id	Front	Top & Side		X	
eim	Front & Top	—	X		
lm	Top & Side	—	X		
og	Top & Front	—	X		

Answers to Assignment Sheets

B.

LINE	VIEW TL IS LOCATED	NON-TL	TYPE OF LINE		
			NORMAL	INCLINED	OBLIQUE
cb	Top	Front & Side		X	
go	Front & Side	—	X		
he	—	Top, Front, & Side			X
fg	Front & Side	—	X		
fb	—	Top, Front, & Side			X
ab	Top & Front	—	X		
gb	Side	Top & Front		X	
hi	Top & Side	—	X		
tu	Top & Side	—	X		

Assignment Sheet 3

A.

PLANE	VIEW TS IS LOCATED	VIEW NON-TS IS LOCATED	VIEW EDGE VIEW IS LOCATED	TYPE OF LINE		
				NORMAL	INCLINED	OBLIQUE
cbf	—	Front & Side	Top		X	
abcde	Top	—	Front & Side	X		
deh	—	Front & Side	Top		X	
tmlu	Top	—	Top & Side	X		
bfg	—	Top & Front	Side		X	

Answers to Assignment Sheets

B.

PLANE	VIEW TS IS LOCATED	VIEW NON-TS IS LOCATED	VIEW EDGE VIEW IS LOCATED	TYPE OF LINE		
				NORMAL	INCLINED	OBLIQUE
abcde	Top	—	Front & Side	X		
bgfc	—	Top & Side	Front		X	
rst	Front	—	Top & Side	X		
mpni	Top	—	Front & Side	X		
end	—	Top, Front, & Side	—		X	

Assignment Sheets 4, 5, 6, 7, 8, 9, and 10

Evaluated according to criteria written in the respective assignment sheets

Sheet Metal Developments
Unit 9

Answers to Written Test

1.	a.	8	e.	3	i.	10	m.	6
	b.	12	f.	11	j.	4	n.	9
	c.	5	g.	14	k.	1	o.	13
	d.	7	h.	16	l.	2	p.	15

2.	a.	3	d.	1
	b.	6	e.	4
	c.	5	f.	2

3. a. Front
   b. Closest to
   c. Front

4. a. Far away from
   b. On the other
   c. Front
   d. Parallel

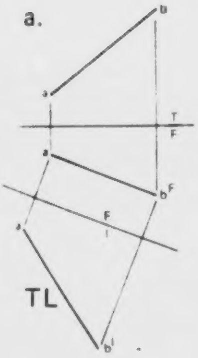
5. a. Perpendicular
   b. Inclined
   c. Oblique

6. a. Lower
   b. TFS

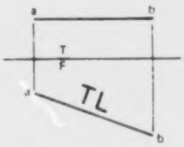
7.	a.	4	e.	5
	b.	7	f.	6
	c.	1	g.	2
	d.	3		

8.

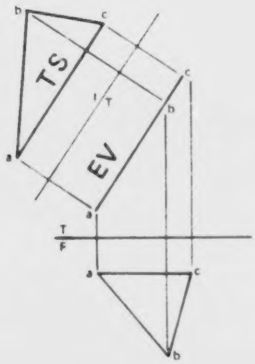
a.


b
a
T
F
a
b F
F
1
a
TL
b1

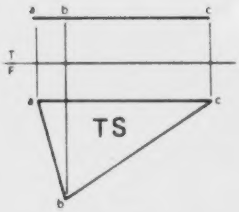
b.



c.

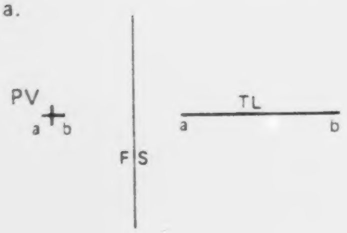

b
c
TS
1
T
c
b
a
EV
a
T
F
a
c
b

d.

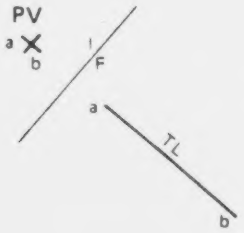

a
b
c
T
F
a
c
TS
b

Answers to Written Test

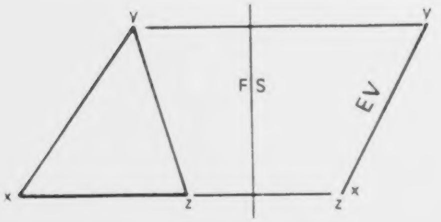
9. a.


PV
a
b
F
S
TL
a
b

b.


PV
a
b
1
F
a
TL
b

c.


y
y
F
S
EV
x
z
z
x

10. b, c

11. a, c

12. Any two of the following:

    a. Edge view given
    b. Auxiliary view method
    c. Cylinders intersecting
    d. Approximate intersections

13. a. 2
    b. 3
    c. 1

14. BA = 2.18″

Sheet Metal Developments
Unit 9

Written Test

Name ______________________ Date ______________ Score __________

1. Match the terms on the right with their correct definitions.

______a. An additional amount of material necessary when making a bend

______b. Where a bend starts

______c. The intersection of a circular cone and a plane

______d. Templates to exact contour of a part used for checking parts at production stages

______e. A pattern of the true sizes of unfolded or unrolled surfaces arranged to be folded to the desired shape

______f. A reference line normally between two views representing the edges of a plane of projection

______g. Original and complete developments of parts used for reference and checking

______h. The intersection of two adjacent surfaces

______i. Drilled or routed holes at intersections of bends to relieve straining which would cause metal to crack or buckle

______j. A cutting plane perpendicular to an axis of a three dimensional form

______k. A method of projection in which the observer stays stationary and the object is rotated for different views of the object

1. Rotation
2. Shrink templates
3. Development
4. Right section
5. Conic section
6. Stretch out line
7. Contour templates
8. Bend allowance
9. Transition piece
10. Relief holes
11. Folding line
12. Bend line
13. True length diagram
14. Master layouts
15. True length of a line
16. Mold line

Written Test

______l. Contour templates made with a shrink scale for die maker and foundry

______m. A line that is perpendicular to each element on which a parallel line development is unrolled or unfolded

______n. A piece that connects two differently shaped conductors

______o. A diagram of the true lengths projected from the normal views

______p. The exact measurable view of the exact length of a line found by observation, projection, or calculation

2. Match surface conditions with their characteristics. Place the number of the surface condition in the blank beside the description of its characteristic.

______a. A surface which has no straight line elements and cannot be developed

______b. Ruled lines on the surface of geometric shapes

______c. Any surface generated by a straight line

______d. A ruled surface generated by a straight line that can be developed

______e. The exact measurable view of the exact size of a surface found by observation, projection, or calculation

______f. A ruled surface that cannot be developed

1. Single curved surface
2. Warped surface
3. Double curved surface
4. True size of a surface
5. Ruled surface
6. Elements of surface

3. Complete statements about guidelines for visualization of near points and planes. Circle the material that best completes each of the following sentences.

   a. In a top view, points or planes are near you when they are observed in the (**front**) (**bottom**) view closest to the arrowhead of the line of sight.

Written Test

b. In a front view, points or planes are near you when they are observed in the top or side view (**farthest from**) (**closest to**) the arrowhead of the line of sight.

c. In a side view, points or planes are near you when they are observed in the (**bottom**) (**front**) view closest to the arrowhead of the line of sight.

4. Complete statements about guidelines for visualization of far points and planes. Circle the material that best completes each of the following statements.

   a. In a top view, points or planes are far from you when they are observed in the front view (**far away from**) (**close to**) or on the other side of the line of sight.

   b. In a front view, points or planes are far from you when they are observed in the top or side view far away or (**on the other**) (**on the same**) side of the line of sight.

   c. In a side view, points or planes are far from you when they are observed in the (**top**) (**front**) view far away from or on the other side of the line of sight.

   d. Points are observed when the line of sight is (**tangent**) (**parallel**) to a true length line where two lines intersect.

5. Complete statements about guidelines for observing planes. Circle the material that best completes each of the following statements.

   a. When line of sight is (**inclined**) (**perpendicular**) to an edge view, the observed plane is in true size.

   b. When line of sight is (**perpendicular**) (**inclined**) to an edge view, the surface is not in true size.

   c. When line of sight is (**oblique**) (**perpendicular**) to an edge view, the surface is not in true size.

6. Complete statements about guidelines for labeling points, lines, and planes. Circle the material that best completes each of the following statements.

   a. Label points with (**lower**) (**upper**) case letters.

   b. Label top, front, and side views (**T,F,S**) (**Top, Front, Side**).

Written Test

7. Arrange in order the steps in constructing an auxiliary view. Place a 1 beside Step 1, a 2 beside Step 2, and complete the remaining steps in order.

_______a. Draw reference or folding line in auxiliary view perpendicular to line of sight at an adequate distance from edge of front view.

_______b. Connect points in auxiliary view that are connected in adjacent view; darken lines.

_______c. Label points of entire object or certain lines or certain planes where an auxiliary view is needed.

_______d. Locate reference or folding line in the adjacent view in either of the following places—back, middle, front, or between views.

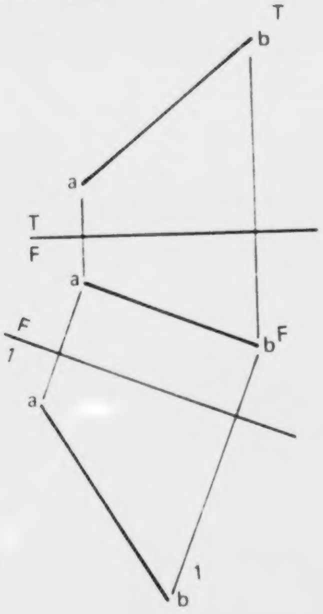
_______e. Draw light projection lines from the points of the view parallel to the line of sight.

_______f. Transfer distances from adjacent view in relation to reference plane using dividers.

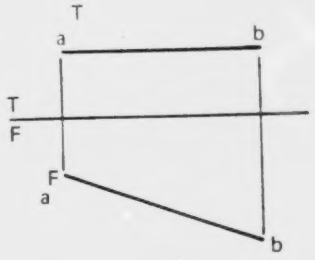
_______g. Select line of sight to get desired view.

8. Identify true length lines and true size planes in the following illustrations. Place a TL on items that are true length, TS on items that are true size, and mark EV on edgeviews of planes.

a.

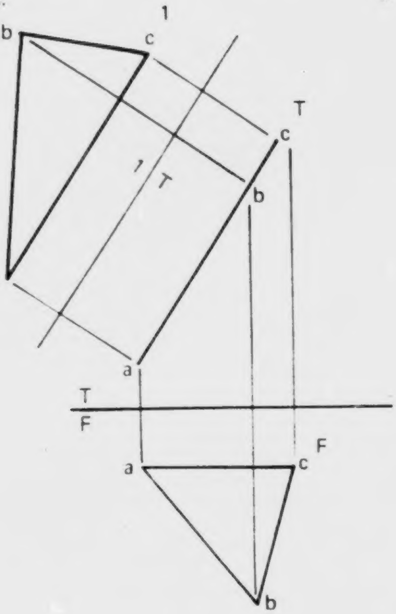


b.

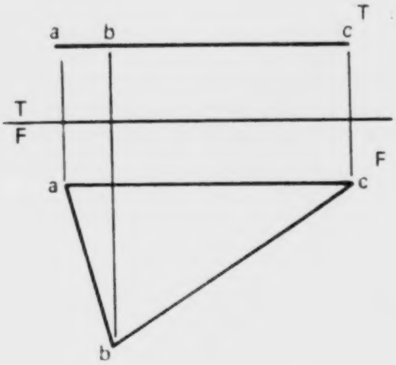


Written Test

c.

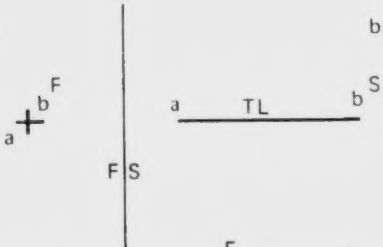

b
c
1
1
T
T
c
b
a
a
T
F
a
c
F
b

d.

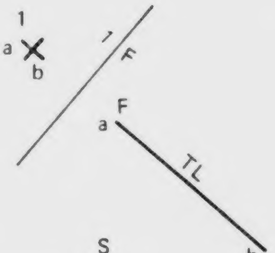

a
b
c
T
T
F
F
a
c
b

9. Identify point views of lines and edge views of planes in the following illustrations. Mark PV on point views and EV on edge views.

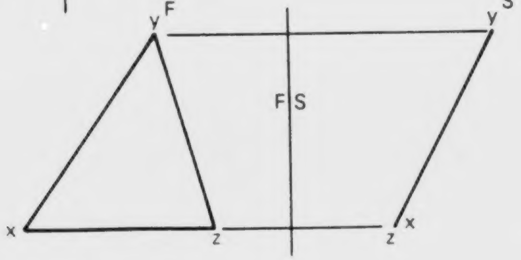
a.


F
b
a
a
TL
b
S
F
S

b.


1
a
b
1
F
F
a
TL
b

c.


y
F
y
S
F
S
x
z
z
x

Written Test

10. Select true statements about rotation characteristics. Place an "X" beside each true statement.

Note: For a statement to be true, all parts of the statement must be true.

______a. The path of rotation of any point not on the axis appears as a rectangle in a view showing the axis of rotation as a point.

______b. The plane of the path of rotation of any point appears in edge view (EV) and perpendicular to the axis in a view showing the axis of rotation in true length.

______c. In true lengths by rotation.

(1) A line may be rotated until it is parallel to a principal plane.

(2) The line is projected onto the adjacent plane.

(3) Since it is parallel to the folding line, it is in true length in the adjacent plane.

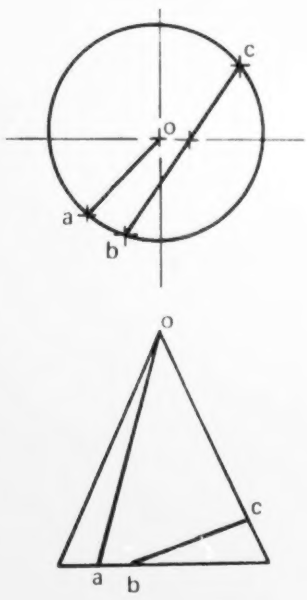
______d. In true sizes by rotation.

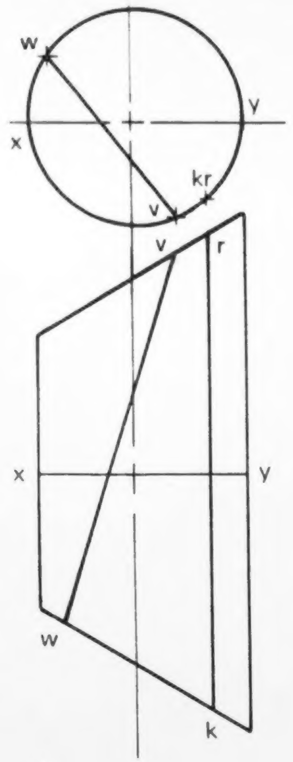
(1) An edge view may be rotated until it is parallel to an orthographic plane.

(2) The edge view is then projected onto the plane and is foreshortened in size.

Written Test

11. Select elements of single curved surfaces. Place an "X" in the blanks that indicate elements.





______a. oa

______b. bc

______c. kr

______d. xy

______e. vw

12. List two methods for finding the intersection of surfaces.

a. ____

b. ____

13. Match general groups of sheet metal developments with their characteristics. Place the number of the development group in the blank beside the definition of its characteristic.

______a. The development of objects that can be developed because of parallel elements on their surfaces

______b. The development of objects that can be developed because of elements radiating from a single point or vertex

1. Triangulation
2. Parallel line development
3. Radial line development

Written Test

______c. A method of developing surfaces which cannot be developed by the parallel line or radial line methods elements on their surfaces

14. Calculate bend allowance for the following conditions: metal thicknesses = .45"; radius = .80"; number of degrees = 125°. Use the following formula, and show all calculations.

$BA = (.017453R + .0078T)N$

BA = ____________

Sheet Metal Developments
Unit 9

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Label Points, Lines, and Planes In Views Rating ______

Comments: ____

____

Assignment Sheet 2—Identify True Lengths and Types of Lines Rating ______

Comments: ____

____

Assignment Sheet 3—Identify True Sizes and Types of Planes Rating ______

Comments: ____

____

Assignment Sheet 4—Construct True Length Lines and
True Size Planes Using Auxiliary Views Rating ______

Comments: ____

____

Assignment Sheet 5—Construct True Lengths of Lines By Rotation Rating ______

Comments: ____

____

Assignment Sheet 6—Construct True Sizes of Planes By Rotation Rating ______

Comments: ____

____

Unit Evaluation Form

Assignment Sheet 7—Locate Elements of Single Curved Surfaces Rating ______

Comments: ______________________________

____

Assignment Sheet 8—Construct Intersections of Surfaces Rating ______

Comments: ______________________________

____

Assignment Sheet 9—Construct Intersections of Surfaces Using The Two-View Method Rating ______

Comments: ______________________________

____

Assignment Sheet 10—Construct Radial Line Developments Rating ______

Comments: ______________________________

____

Assignment Sheet 11—Construct Parallel Line Developments Rating ______

Comments: ______________________________

____

Assignment Sheet 12—Construct Special Developments Using Triangulation Rating ______

Comments: ______________________________

____

Pretest ______ Posttest ______ Other ______

Other ______________________________

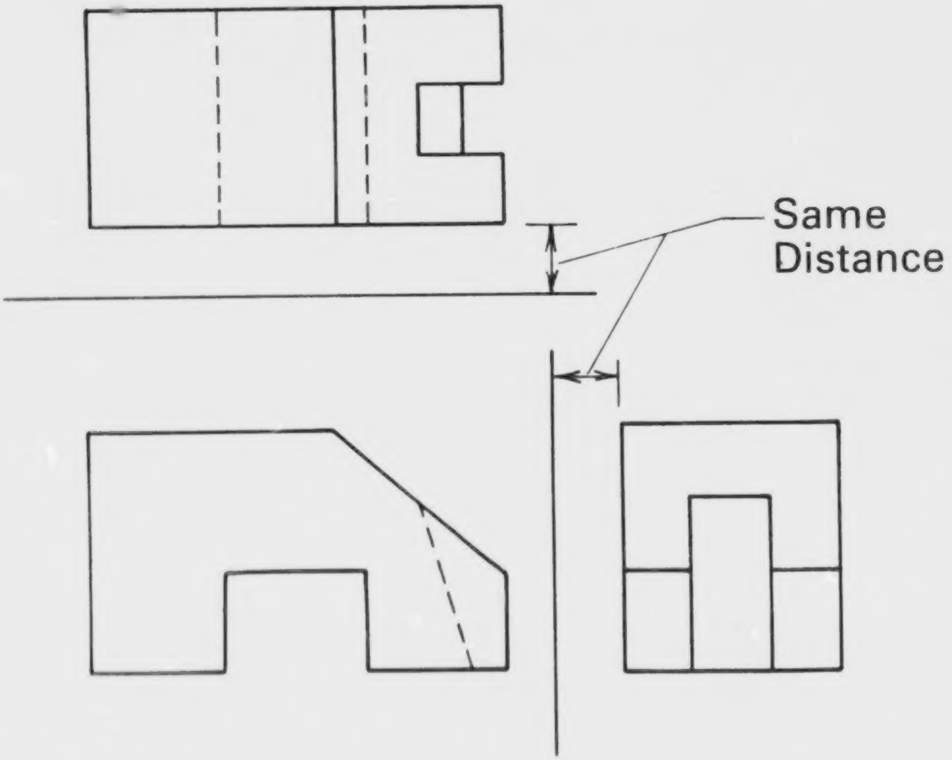
____

Teacher Signature ______________________________ Date ______________

Student Signature ______________________________ Date ______________

***Permission to duplicate this form is granted.**

Labeling Points, Lines, and Planes

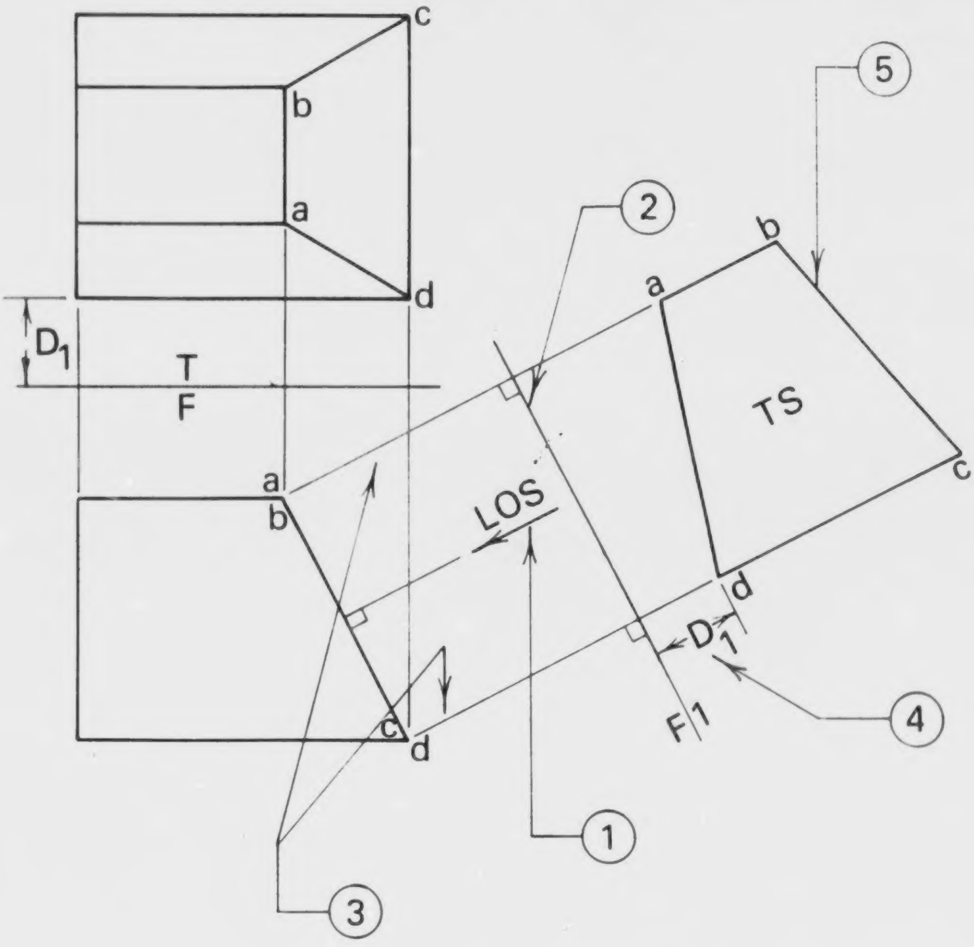


NOTE: The labeling of points, lines, and planes on this transparency are meant to be supplied by the instructor.

Steps for Constructing Auxiliary Views

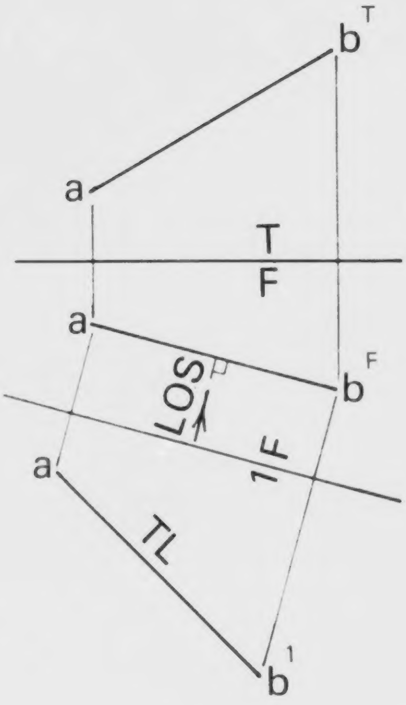
Folding Line Method

1. Line of Sight—LOS
2. Folding Line—⊥ to LOS
3. Project ⊥ to Folding Line
4. Transfer Distances
5. Complete the View

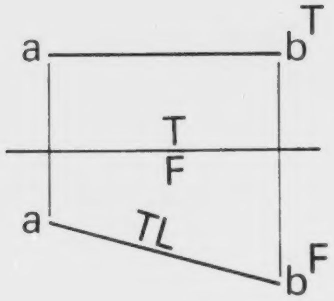


c
b
a
d
D_1
T
F
a
b
c
d
LOS
F
1
a
b
TS
c
d
D_1
①
②
③
④
⑤

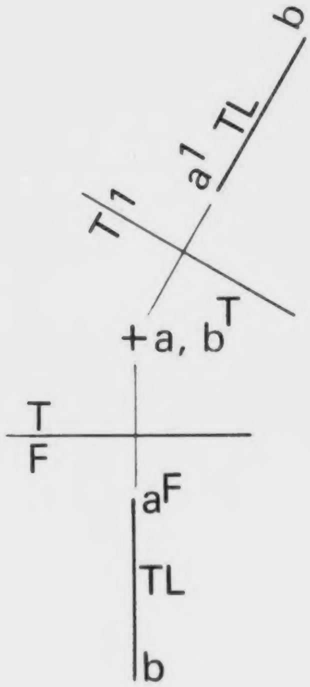
True Lengths of Lines


b^T
a
T
F
a
b^F
LOS
1F
a
TL
b^1

From Line of
Sight Being
⊥ to Line

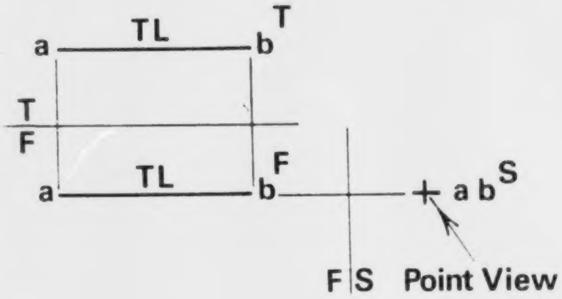

a
b^T
T
F
a
TL
b^F

From Folding
Line Being Parallel to Line


b
TL
a1
T1
+a, b^T
T
F
a^F
TL
b

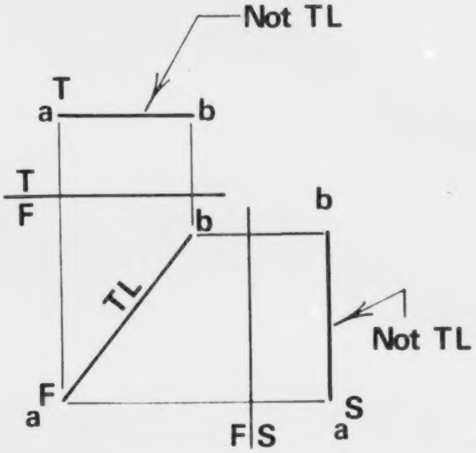
From Point
View

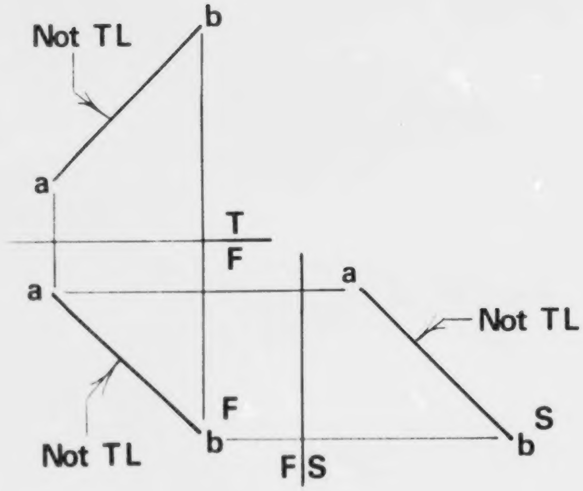
Identifying True Lengths


a
TL
b
T
T
F
a
TL
b
F
a b
S
F|S
Point View

Normal Line

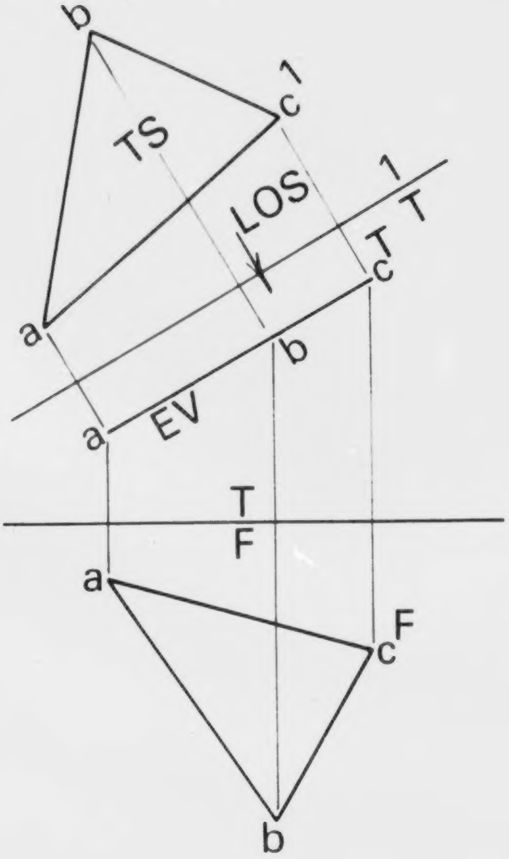
Inclined Line


Not TL
a
T
b
T
F
b
b
TL
Not TL
a
F
F|S
a
S

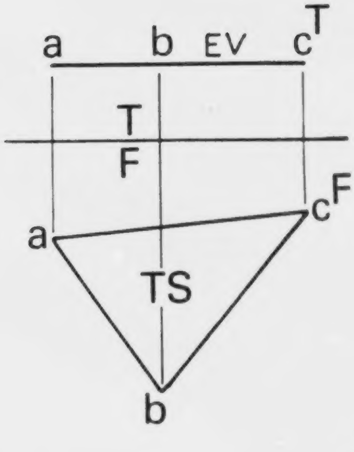

T
b
Not TL
a
T
F
a
a
Not TL
F
Not TL
b
F|S
b
S

Oblique Line

Observing True Size Planes

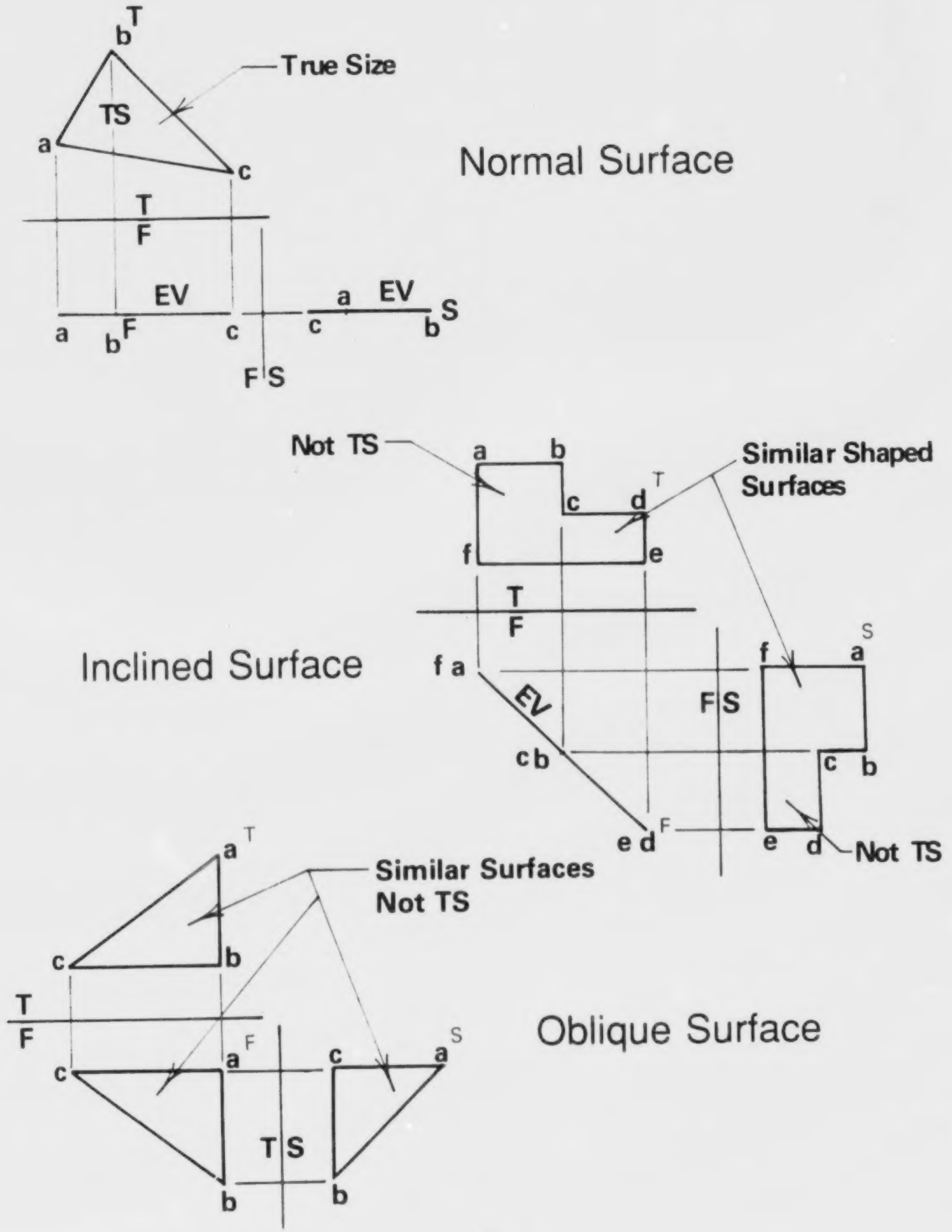

b
c 1
TS
LOS
1 T
c T
a
b
a
EV
T
F
a
c F
b

Line of
Sight ⊥
To Edge
View

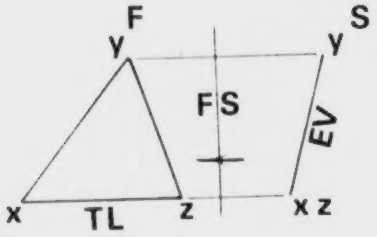

a
b
EV
c T
T
F
a
c F
TS
b

Folding Line
Parallel to
Edge View

Identifying True Sizes

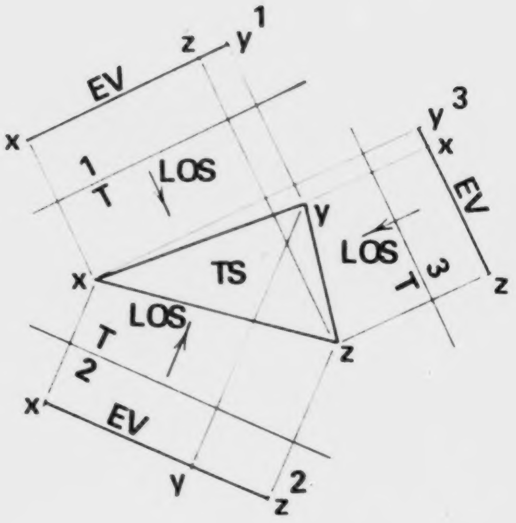

b T
True Size
TS
a
c
Normal Surface
T
F
EV
a EV
a
b F
c
c
b S
F S
Not TS
a
b
Similar Shaped Surfaces
c
d T
f
e
T
F
Inclined Surface
f a
EV
F S
f
a S
c b
c
b
e d F
e
d
Not TS
a T
Similar Surfaces Not TS
c
b
T
F
Oblique Surface
c
a F
c
a S
T S
b
b

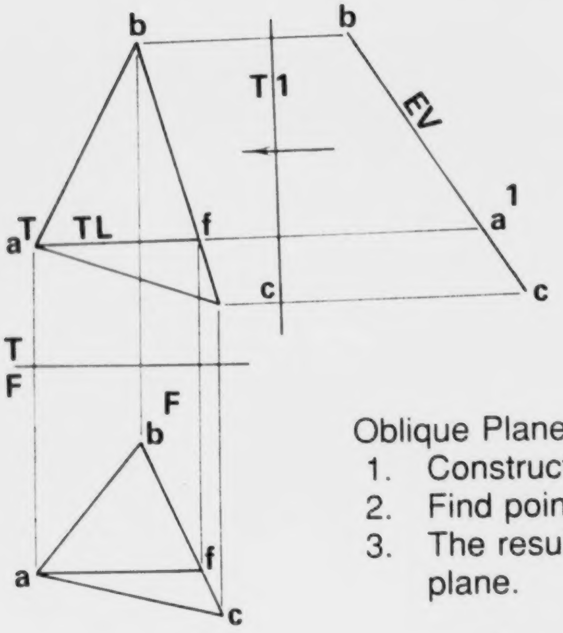
Edge Views of Planes


F
S
y
y
F S
EV
x
TL
z
x z

LOS Parallel to TL Line in the Plane

LOS Pointing to any View of TS Plane Will Give an Edge View

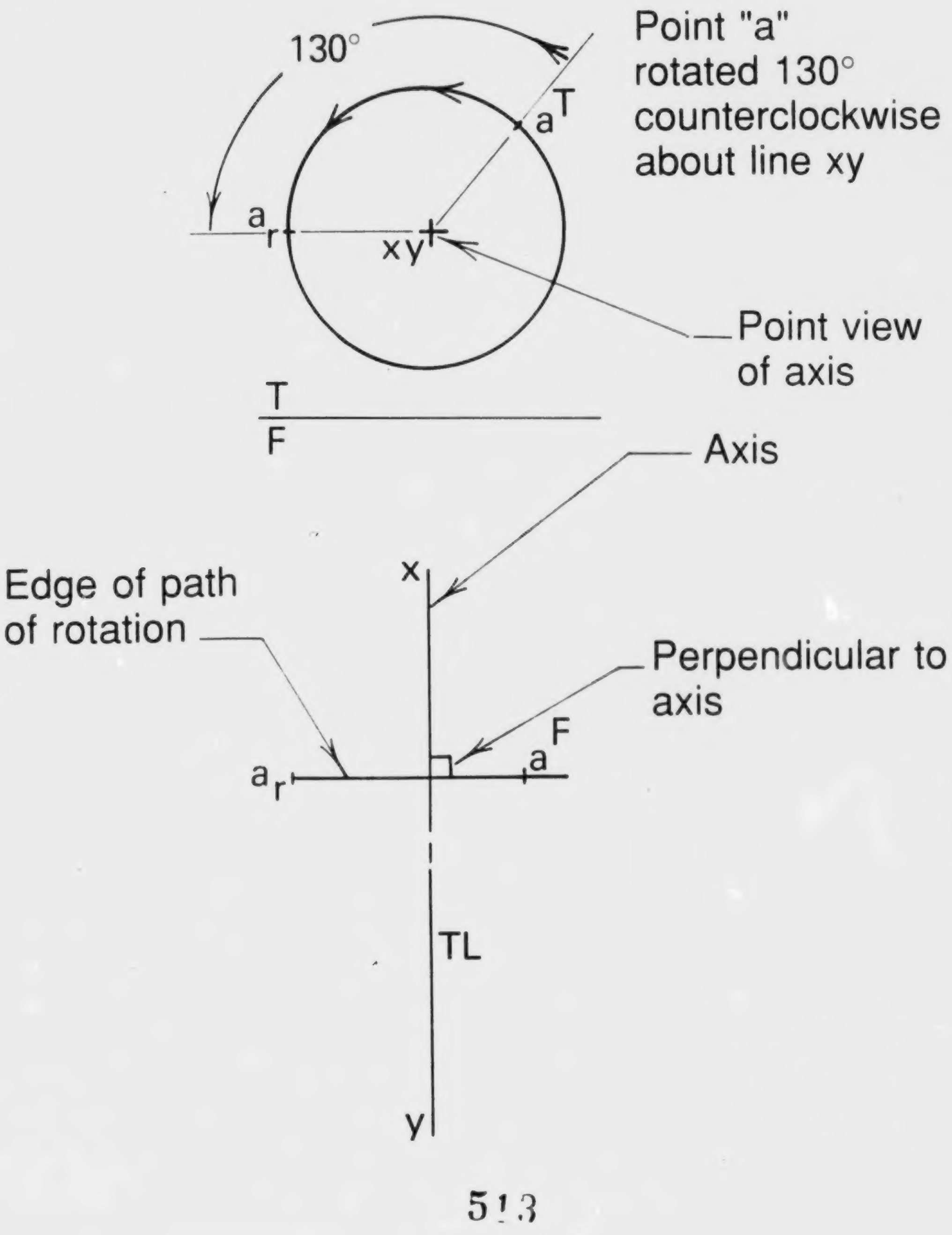

z
y
1
EV
x
1
T
LOS
y
3
x
EV
y
LOS
x
TS
3
T
z
LOS
T
z
2
x
EV
y
2
z


b
b
T 1
EV
1
a
a
T
TL
f
c
c
T
F
F
b
a
f
c

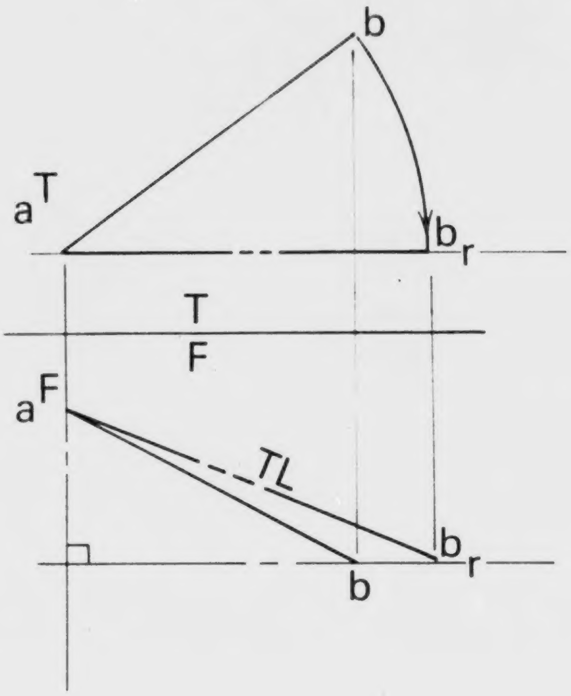
Oblique Plane

1. Construct TL line af in one view.
2. Find point view of TL line.
3. The result is an edge view of the plane.

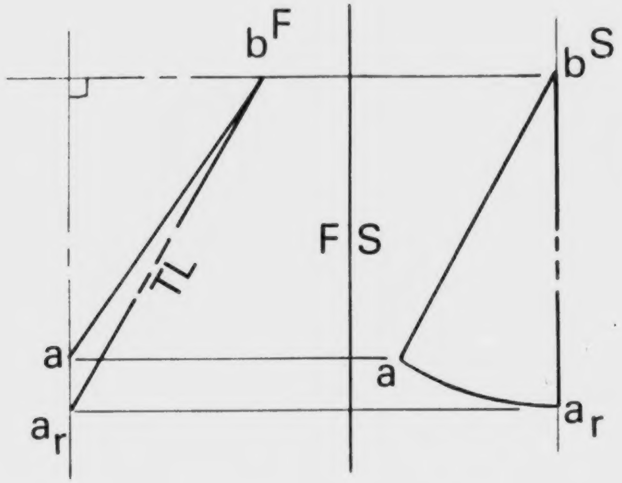
Rotation of a Point


130°
Point "a" rotated 130° counterclockwise about line xy
a^T
a_r
xy
Point view of axis
T
F
Axis
x
Edge of path of rotation
Perpendicular to axis
a^F
a_r
TL
y

True Lengths by Rotation

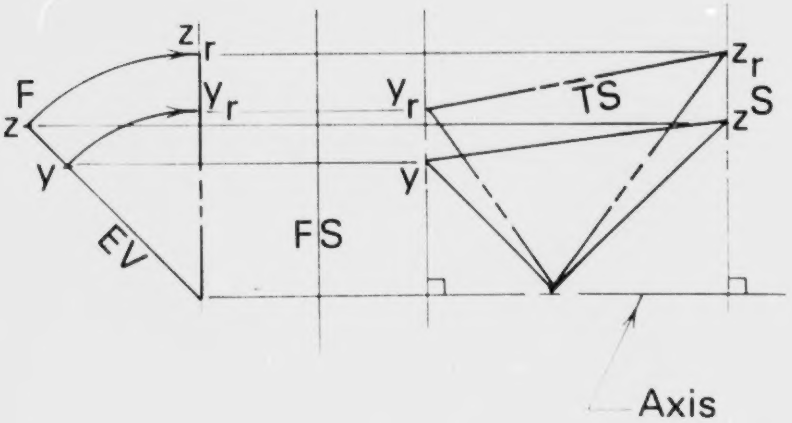

b
a^T
b_r
T
F
a^F
TL
b_r
b

(a)

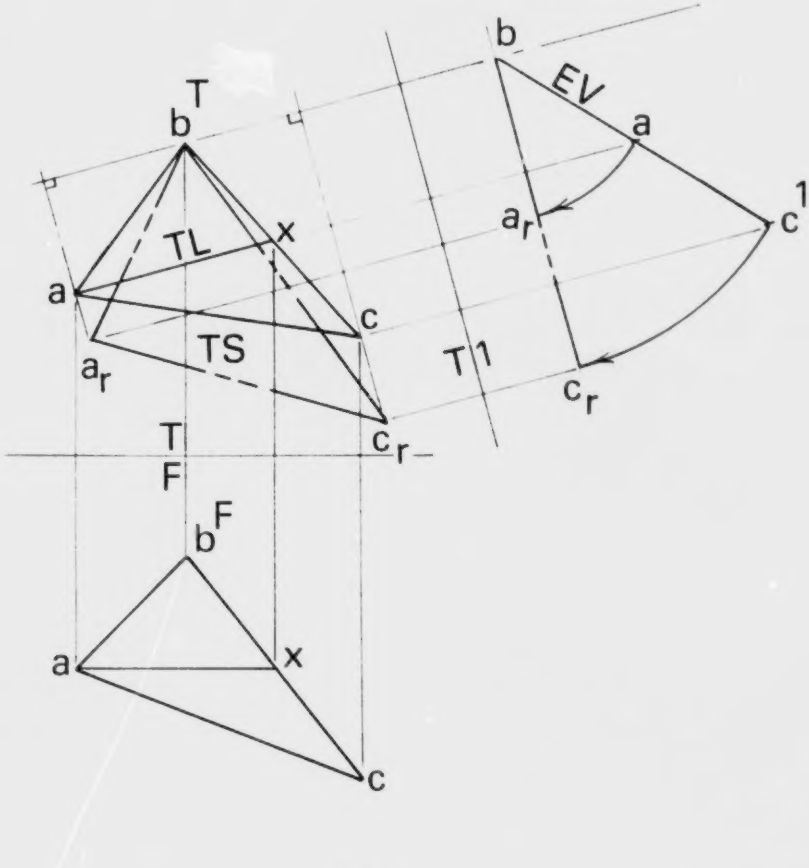

b^F
b^S
F S
TL
a
a
a_r
a_r

(b)

True Sizes by Rotation

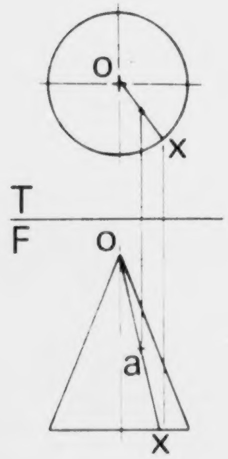


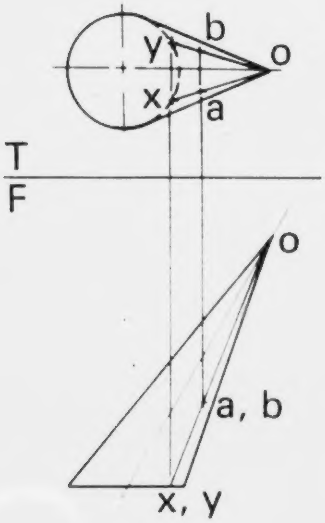
z_r
F
z
y_r
y
EV
FS
y_r
y
TS
z_r
z^S
Axis

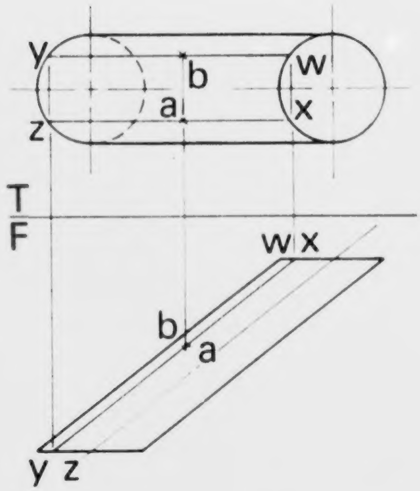


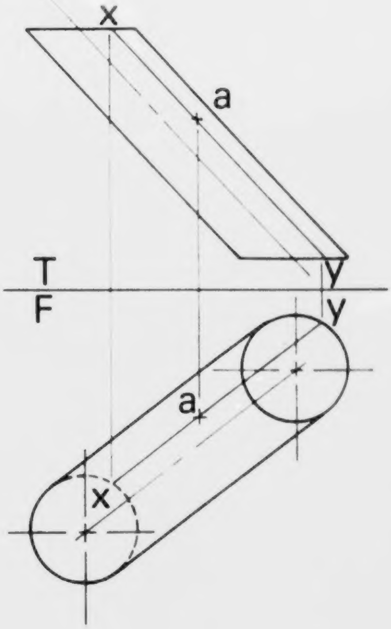
b
EV
b^T
a
x
TL
a_r
c^1
a
c
TS
T1
a_r
c_r
T
c_r
F
b^F
a
x
c

Elements of Single Curved Surfaces

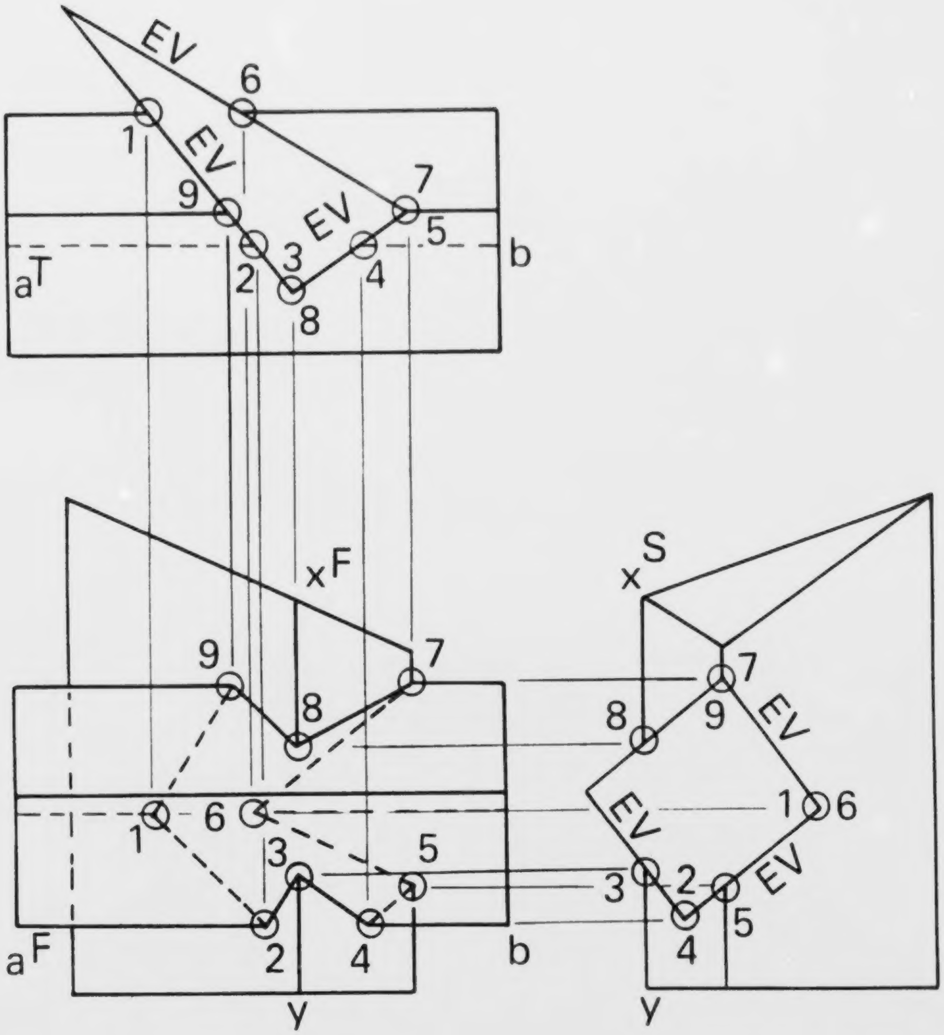



y
b
o
x
a
T
F
o
a, b
x, y

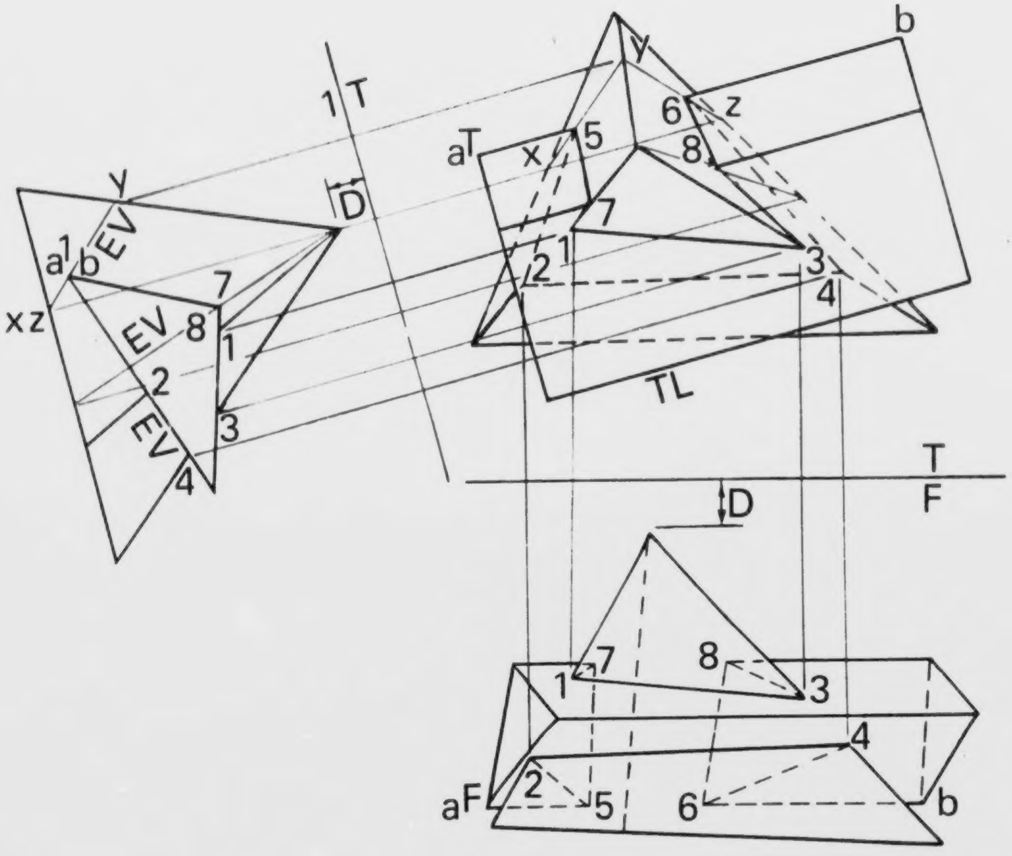

y
b
w
a
x
z
T
F
w x
b
a
y z



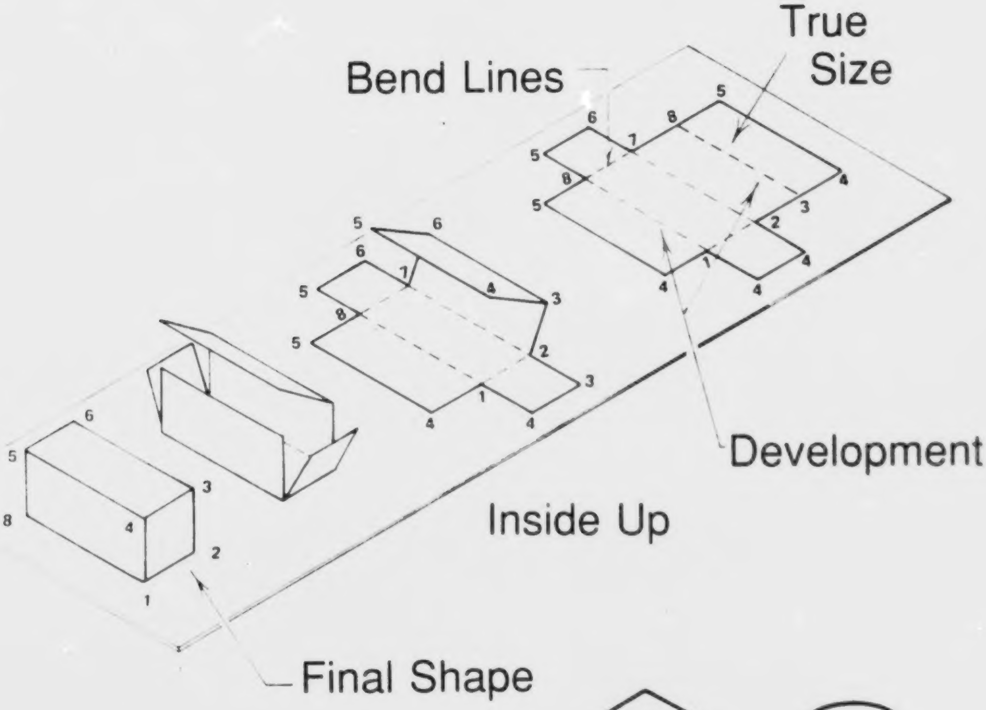
Intersections With Edge View Given

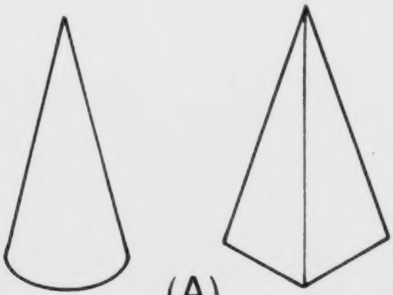

EV
6
1
EV
9
EV
7
5
b
aT
2
3
4
8
xF
9
7
8
1
6
3
5
aF
2
4
b
y
xS
7
8
9
EV
1
6
EV
3
2
EV
4
5
y

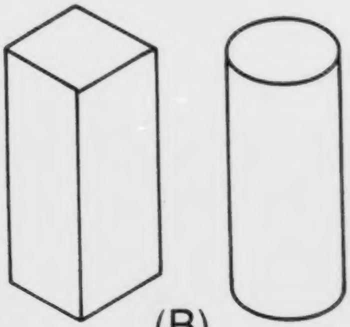
Intersections Using Auxiliary Views

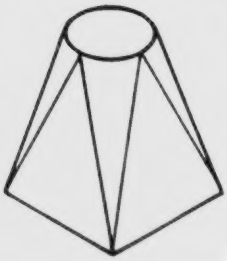

b
y
1
T
6
z
a
T
x
5
8
y
D
EV
a
1
b
7
3
xz
EV
8
2
1
4
1
2
TL
3
EV
T
4
F
D
7
8
1
3
4
a
F
2
5
6
b

Developments


True Size
Bend Lines
5
6
8
7
5
8
5
4
3
2
4
1
4
4
5
6
6
7
5
4
3
8
5
2
1
3
4
4
6
5
3
8
4
2
1
Development
Inside Up
Final Shape

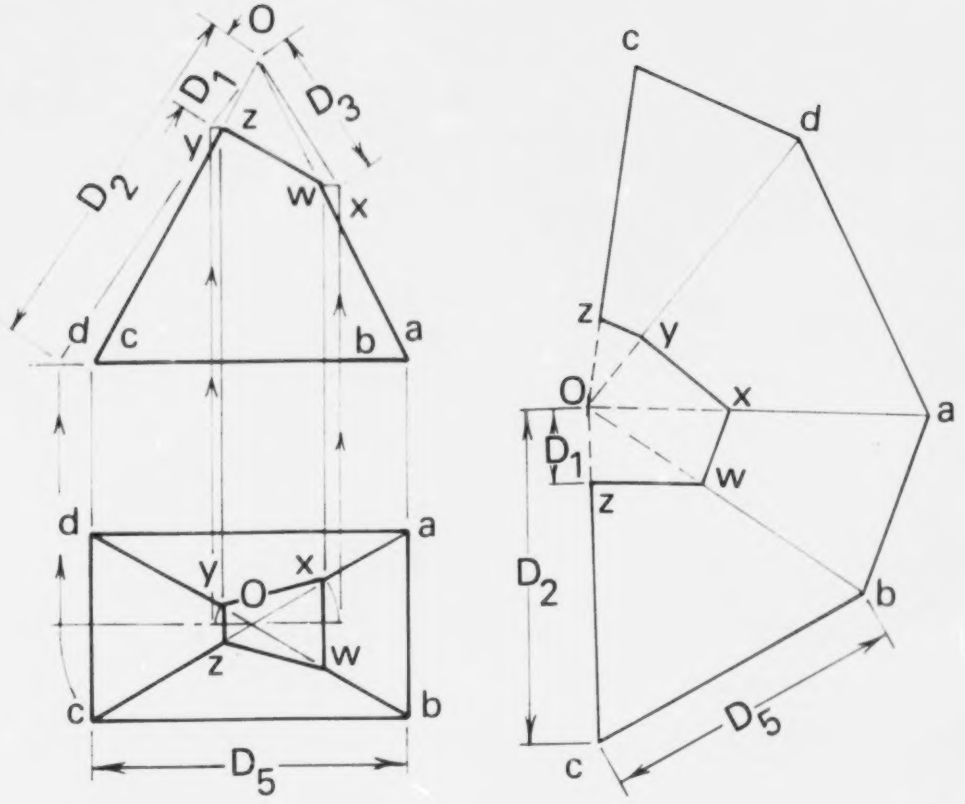

(A)
Radial Line


(B)
Parallel Line

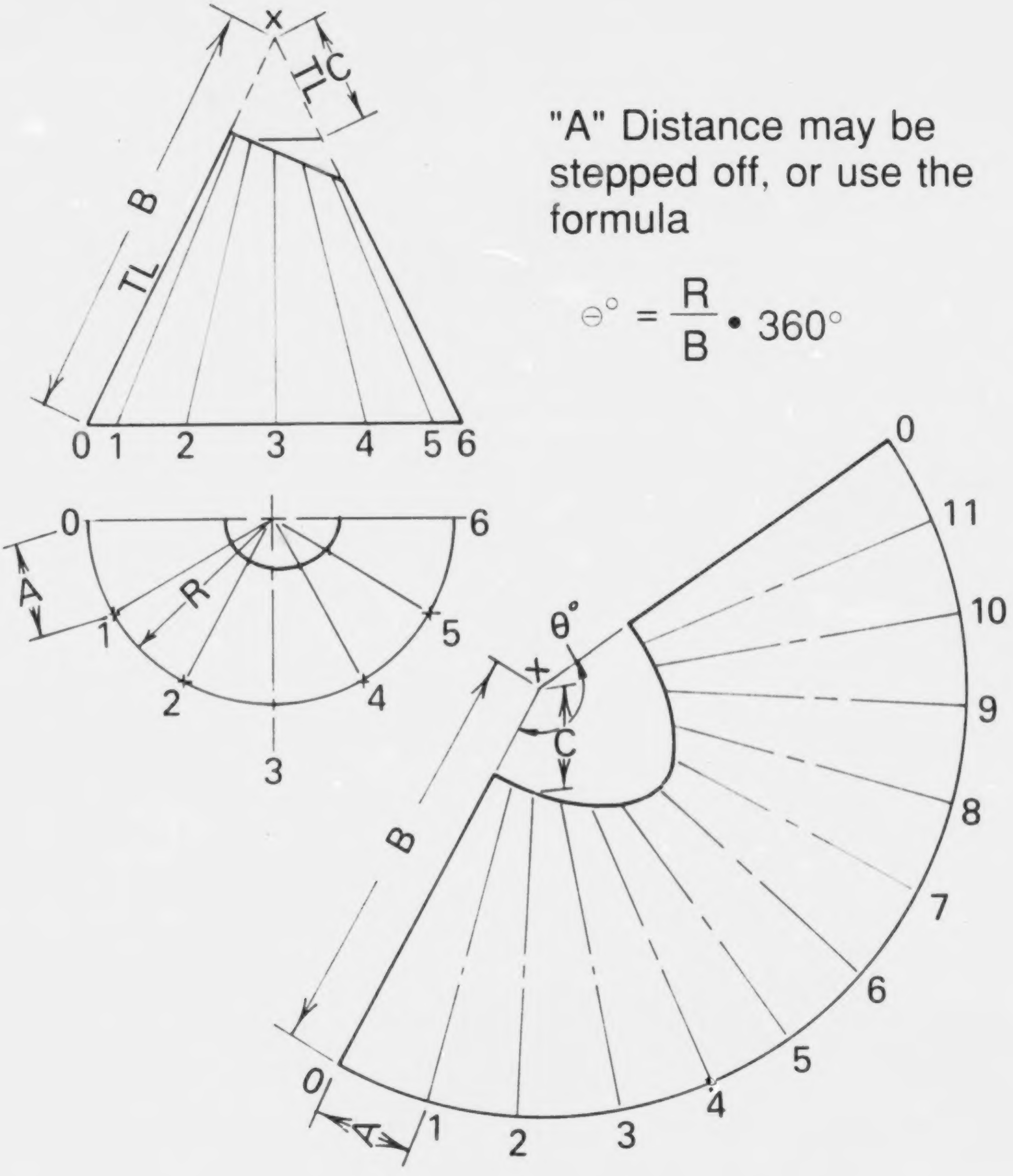

(C)
Triangulation

519

Radial Line Developments
Pyramids


O
D1
D3
D2
z
y
w
x
d
c
b
a
d
a
y
x
O
z
w
c
b
D5
c
d
z
y
O
x
a
D1
w
z
D2
b
D5
c

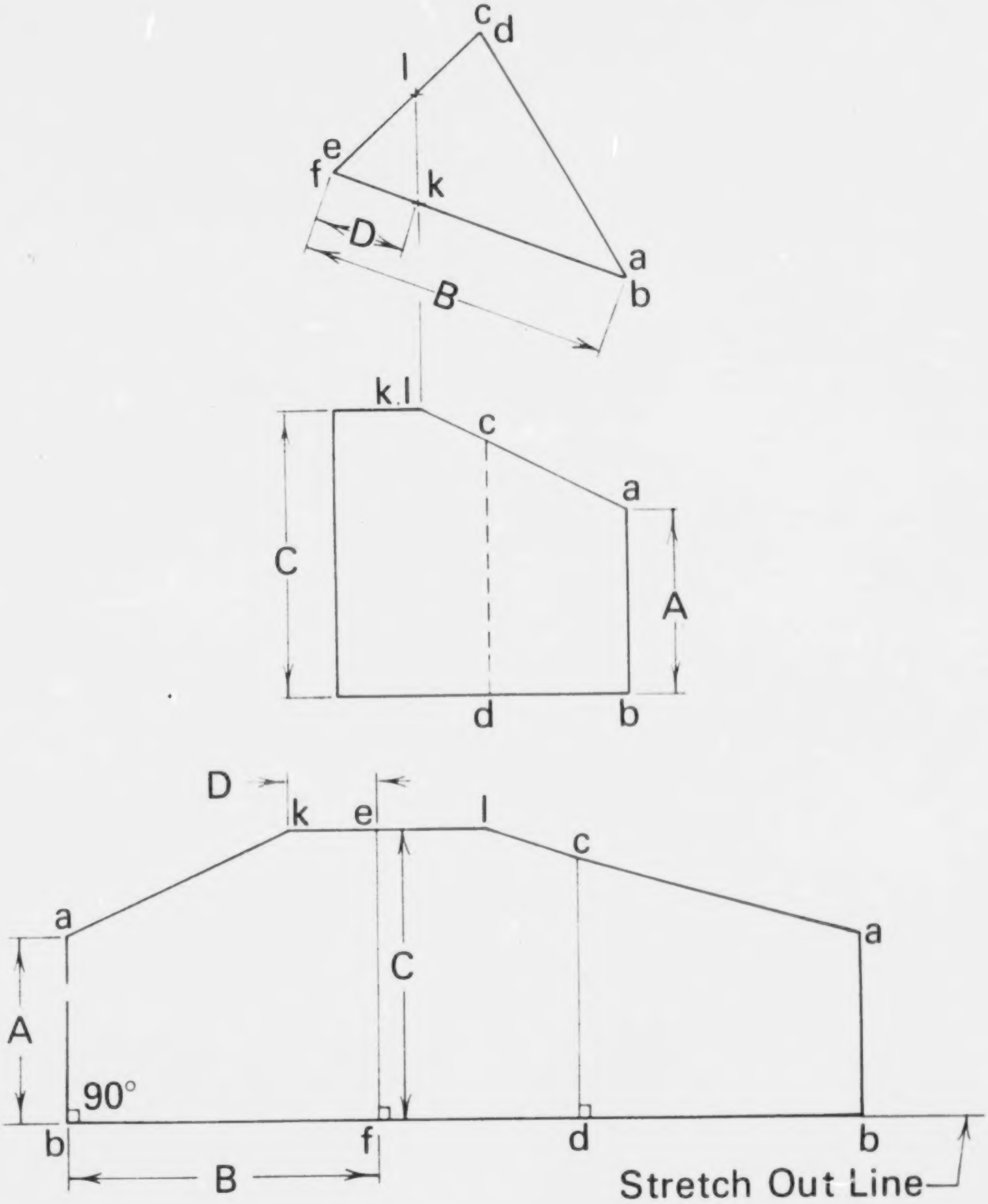
Radial Line Developments
Cones


x
C
TL
B
TL
0 1 2 3 4 5 6
0
6
A
R
1
5
2
4
3
θ°
C
B
0
11
10
9
8
7
6
5
4
3
2
1
0
A

"A" Distance may be stepped off, or use the formula

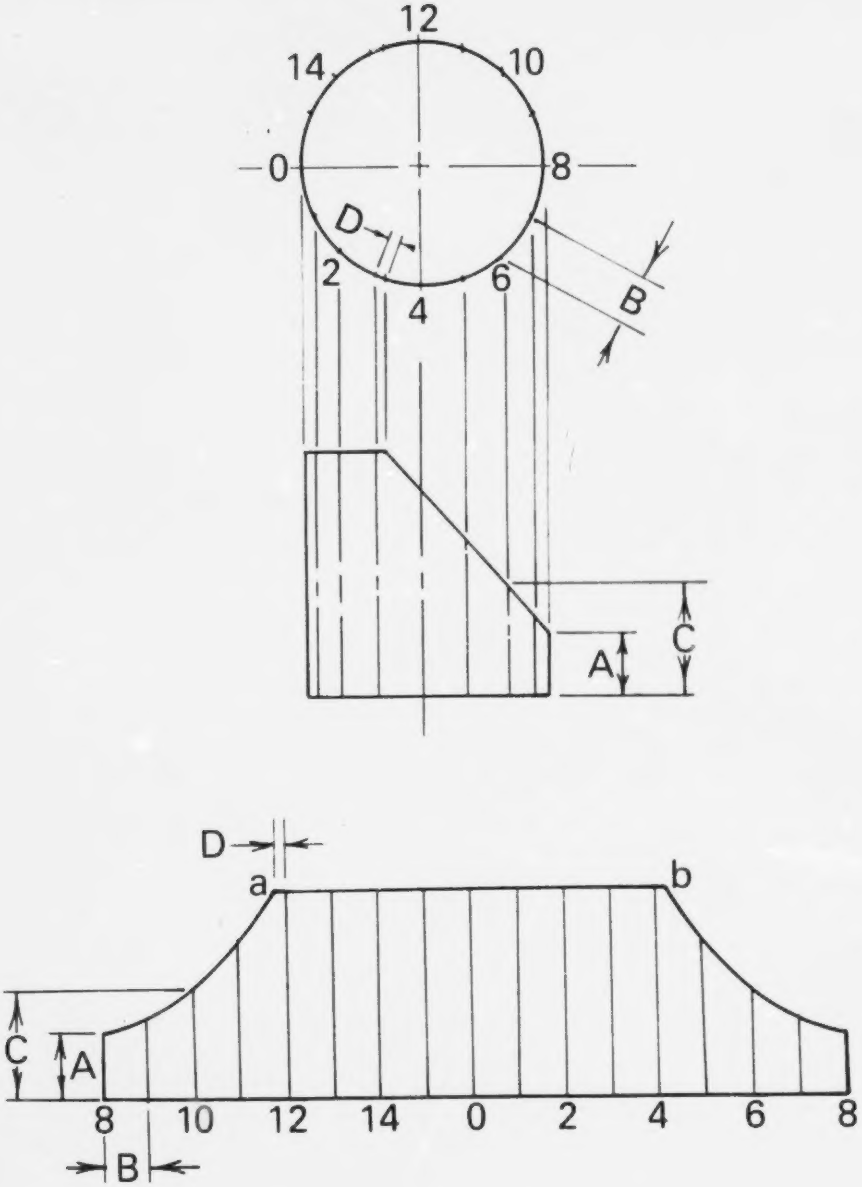
$$\theta^\circ = \frac{R}{B} \cdot 360^\circ$$

Parallel Line Developments
Prisms

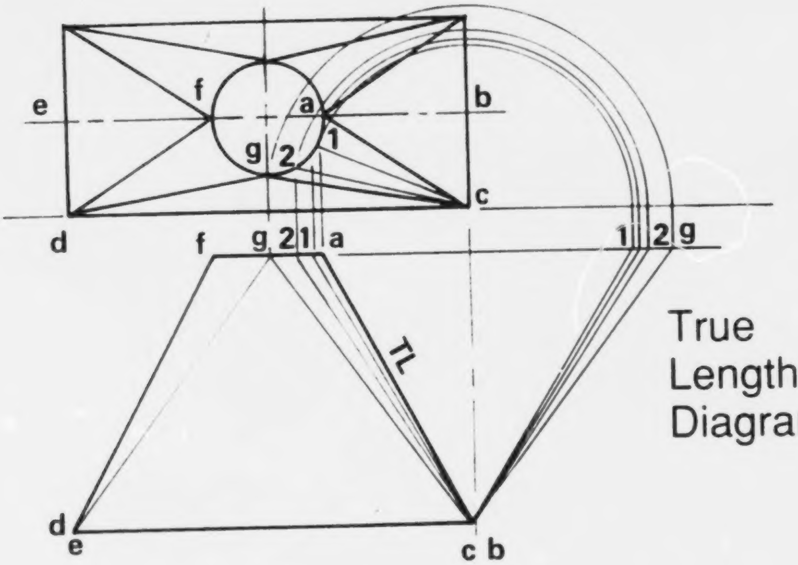


c d
l
e
f
k
D
a
b
B
k.l
c
a
C
A
d
b
D
k
e
l
c
a
a
C
A
90°
b
f
d
b
B
Stretch Out Line

Parallel Line Developments
Cylinders

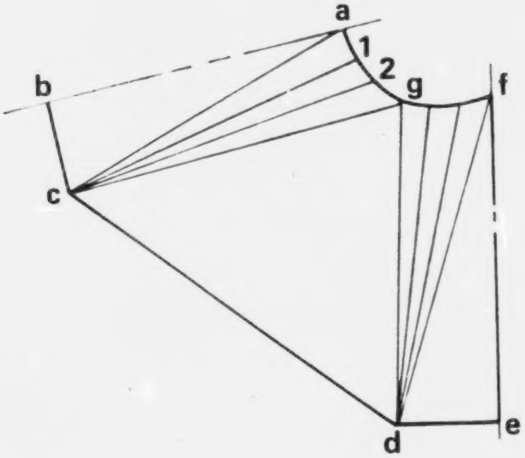

12
14
10
0
8
D
2
6
4
B
C
A
D
a
b
C
A
8
10
12
14
0
2
4
6
8
B

Triangulation


e
f
a
b
g
2
1
c
d
f
g
2
1
a
1
2
g
TL
d
e
c
b

True
Length
Diagram

Half Development



Sheet Metal Developments
Unit 9

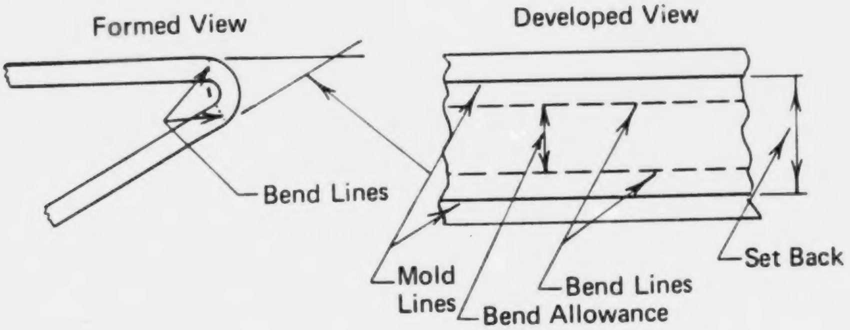
Information Sheet

1. **Terms and definitions**

   a. **Bend allowance (BA)** — An additional amount of material necessary when making a bend

   Note: Usually BA is calculated for material over .65 mm thick.

   b. **Bend line** — Where bend starts



   c. **Conic section** — The intersection of a circular cone and a plane

   d. **Contour templates** — Templates to exact contour of part used for checking parts at production stages

   e. **Development** — A pattern of the true sizes of unfolded or unrolled surfaces arranged to be folded to the desired shape

   f. **Folding line** — A reference line normally between two views representing the edge of a plane of projection

   g. **Master layouts** — Original and complete developments of parts used for reference and checking

   h. **Mold line (IML)** — The intersection of two adjacent surfaces

   Note: Inside surface intersections are called "inside mold line" (ML) and outside surface intersections are called "outside mold lines" (OML).

   i. **Relief holes** — Drilled or routed holes at intersection of bends to relieve strain which would cause metal to crack or buckle

Information Sheet

j. **Right section** — A cutting plane perpendicular to an axis of a three dimensional form

Note: The axis may be the center line of a cylinder, cone, or true lengths of a prism, square, or hexagon shape.

k. **Rotation** — A method of projection in which the observer stays stationary and the object is rotated for different views of the object

l. **Shrink templates** — Contour templates made with a shrink scale for die maker and foundry

m. **Stretch out line** — A line that is perpendicular to each element on which a parallel line development is unrolled or unfolded

n. **Transition piece** — A piece that connects two differently shaped conductors

o. **True length diagram** — A diagram of the true lengths projected from the normal views

p. **True length of a line** — The exact measurable view of the exact length of a line found by observation, projection, or calculation

2. **Surface conditions and their characteristics**

a. **Double curved surface** — A surface which has no straight line elements and cannot be developed

Examples: Sphere, cone, paraboloid, hyperboloid, approximation developments are possible

b. **Elements of a surface** — Ruled lines on the surface of geometric shapes

c. **Ruled surface** — Any surface generated by straight lines

Note: this may be a plane, single curved surface, or a warped surface.

d. **Single curved surface** — A ruled surface generated by a straight line that can be developed

e. **True size of a surface** — The exact measurable view of the exact size of a surface found by observation, projection, or calculation

f. **Warped surface** — A ruled surface that cannot be developed

Examples: Oblique helicoid, cylindroid, many exterior surfaces on an airplane, approximation developments are possible

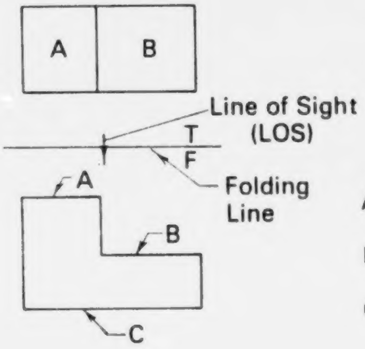
Information Sheet

3. Guidelines for visualization of near points and planes

a. In a top view, points or planes are near you when they are observed in the front view closest to the arrowhead of the line of sight (LOS).

b. In a front view, points or planes are near you when they are observed in the top or side view closest to the arrowhead of the line of sight (LOS).

(Observer Looking Down On Top View)



A – Near observer

B – Near observer

C – Far from observer

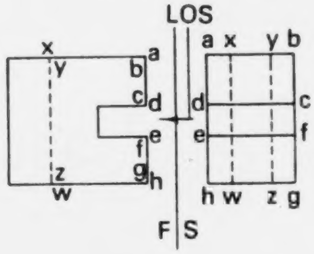
c. In a side view, points or planes are near you when they are observed in the front view closest to the arrowhead of the line of sight (LOS).

4. Guidelines for visualization for far points and planes

a. In a top view, points or planes are far from you when they are observed in the front view far away from or on the other side of the line of sight.

b. In a front view, points or planes are far from you when they are observed in the top or side view far away from or on the other side of the line of sight.

(Observer Looking On Right Side of Object)



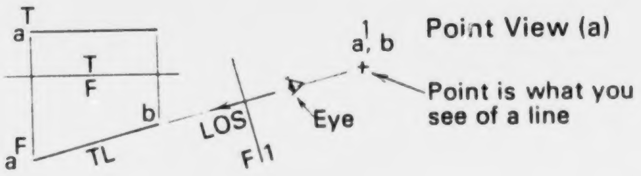
Points a b c d e f g h are near observer

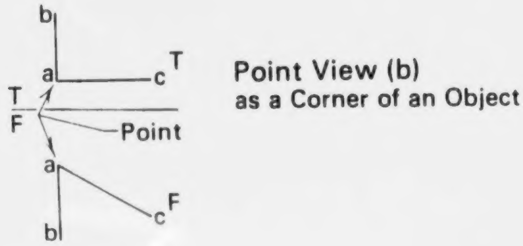
Points x y z w are far from observer

c. In a side view, points or planes are far from you when they are observed in the front view far away from or on the other side of the line of sight.

Information Sheet

d. Points are observed when the line of sight is parallel to a true length line or where two lines intersect.


a^T
T
F
b
a^F
TL
LOS
F 1
Eye
a, b
Point View (a)
Point is what you see of a line

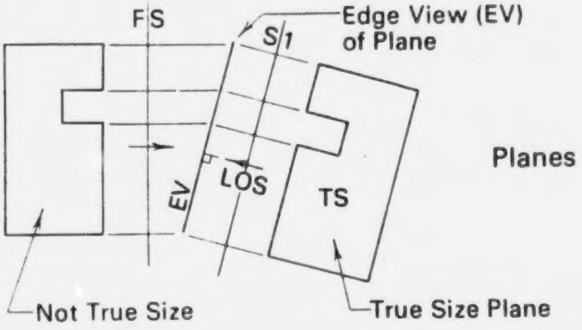

b
a
c^T
T
F
Point
a
c^F
b
Point View (b)
as a Corner of an Object

5. Guidelines for observing planes

a. When line of sight is perpendicular to an edge view, the observed plane is in true size.

b. When line of sight is inclined to edge view, the surface is not in true size.

Note: In principal views, the surface is inclined if LOS is inclined to the edge view.


F S
S 1
Edge View (EV) of Plane
EV
LOS
TS
Planes
Not True Size
True Size Plane

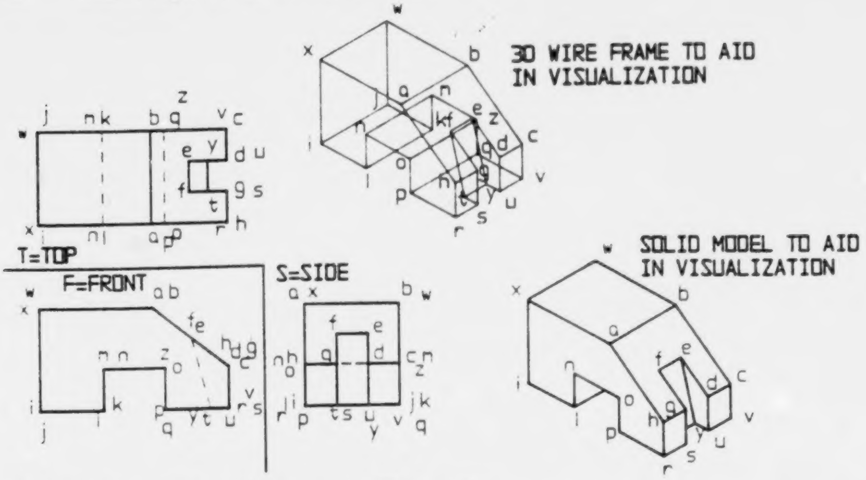
c. When line of sight is oblique to edge view, the surface is not in true size.

Note: In principal views, the surface is oblique if an edge view of the plane is not observed. In other words, the plane appears not in true size in all of the principal planes, and no edge view is observed.

6. **Guidelines for labeling points, lines, and planes**

   a. Label points with lower case letters.

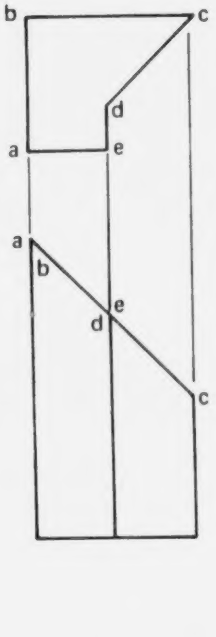
   b. Label top, front, and side views T, F, S.


3D WIRE FRAME TO AID IN VISUALIZATION
SOLID MODEL TO AID IN VISUALIZATION
T=TOP
F=FRONT
S=SIDE

7. **Steps for constructing an auxiliary view**

   a. Label points of entire object or certain lines or certain planes where an auxiliary view is needed.

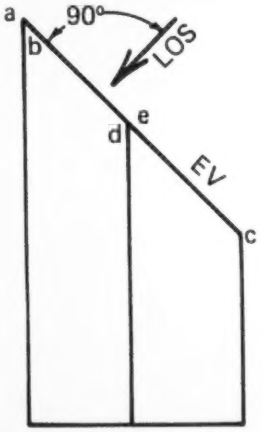
   Example: Find TS of plane abcde.


b
c
d
a
e
a
b
e
d
c

Information Sheet

b. Select line of sight to get desired view.

Example: Line of sight is perpendicular to edge view of plane abcde that is to be drawn true size.

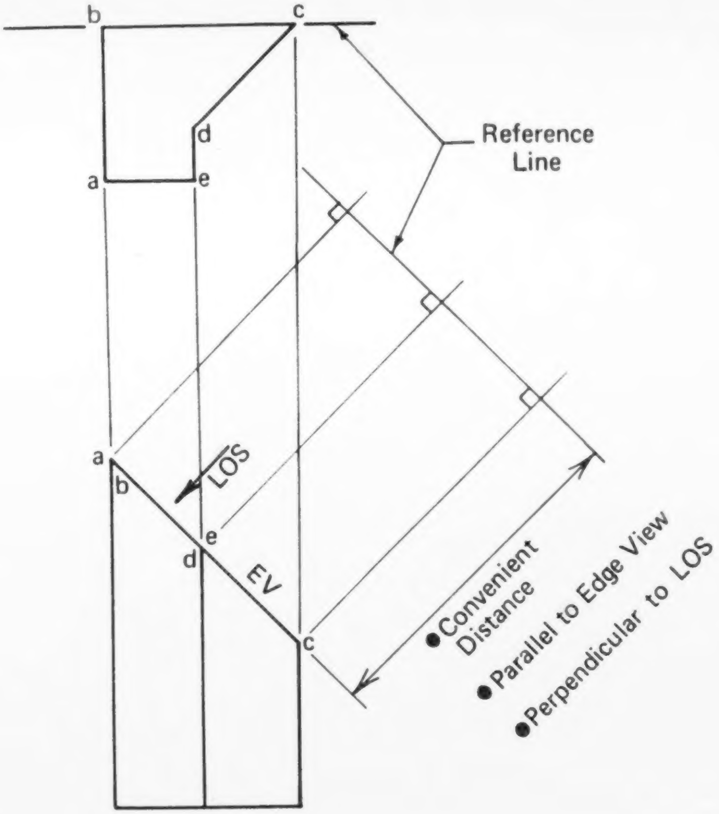


c. Locate reference or folding line in the adjacent view in either of the following places—back, middle, front, or between views.

Note: When line is between views, it is called a folding line. When line is on the object, it is called a reference line.

Information Sheet

Example: The back is selected in the top view.


b
c
d
a
e
Reference Line
a
b
LOS
e
d
EV
c
●Convenient Distance
●Parallel to Edge View
●Perpendicular to LOS

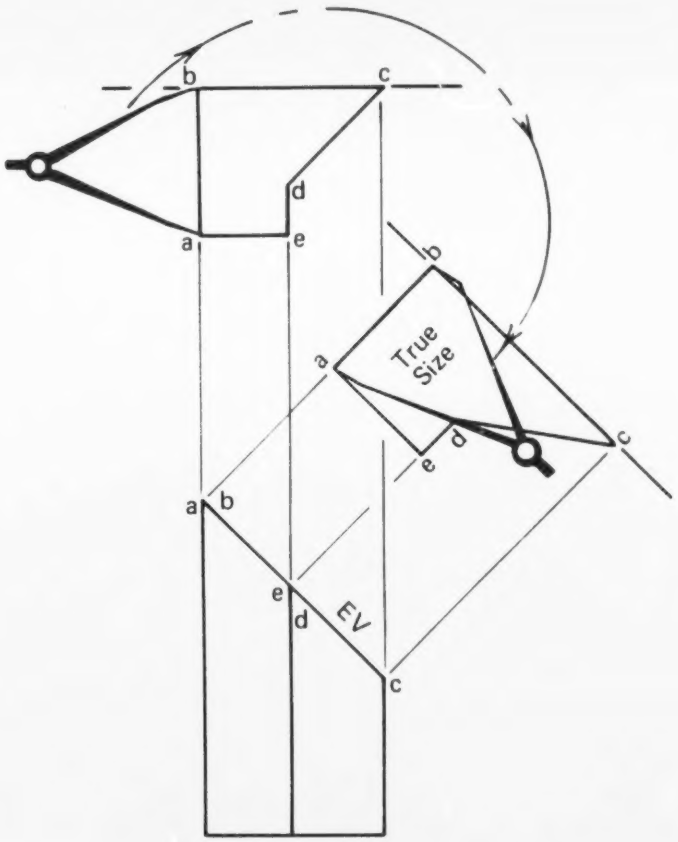
d. Draw reference or folding line in auxiliary view perpendicular to line of sight at an adequate distance from edge of front view.

e. Draw light projection lines from the points of the view parallel to the line of sight.

Note: Projection lines will be perpendicular to reference line.

Information Sheet

Example: Draw projection lines.



f. Transfer distances from adjacent view in relation to reference plane using dividers.

Example: Transfer points a, e, d. Since b and c are on reference line, mark the points on the reference line.

g. Connect points in auxiliary view that are connected in adjacent view; darken lines.

Example: Connect points abcde and back to a.

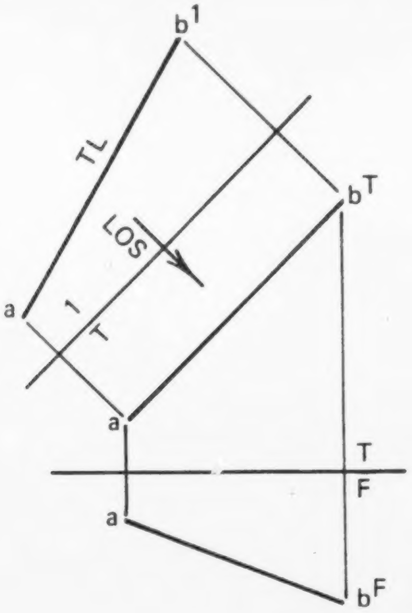
Note: Notice the similar shape of the surface in the top view which has 5 lines and in the auxiliary view which has 5 lines.

Information Sheet

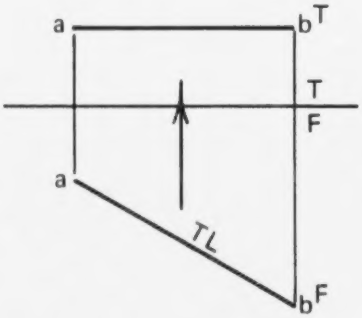
8. Guidelines for observing true length lines and true size planes

a. True length lines are observed when:

(1) The line of sight is perpendicular to a line-an oblique line.

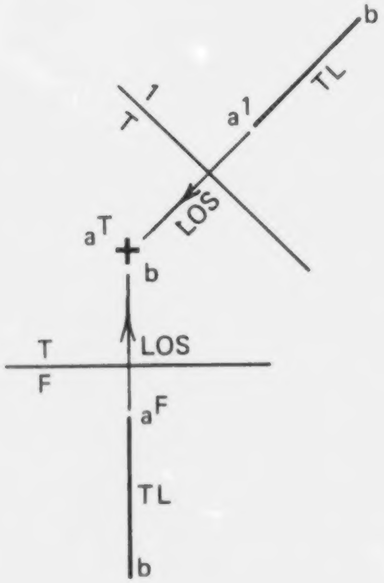

b1
TL
bT
LOS
a
1
T
a
T
F
a
bF

(2) The folding line is parallel to a line and line of sight is perpendicular to line—an inclined line.

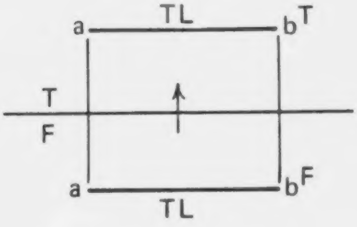

a
bT
T
F
a
TL
bF

Information Sheet

(3) The line of sight points to the point view of a line.


b
TL
a1
T
1
LOS
aT
b
LOS
T
F
aF
TL
b

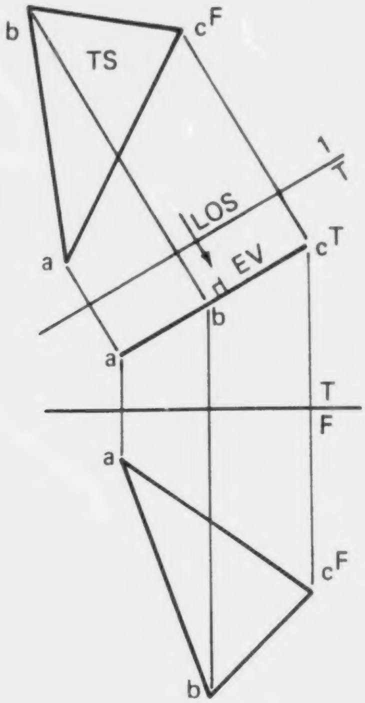
(4) Both lines are parallel to the folding line—a normal line.


a
TL
bT
T
F
a
bF
TL

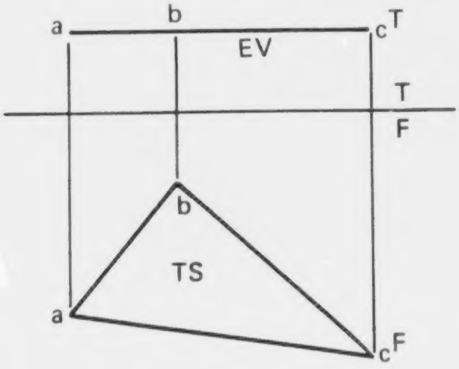
Information Sheet

b. True size of a plane is observed when:

(1) The line of sight is perpendicular to the edge view of the plane—an inclined plane.


b
c^F
TS
1
T
LOS
EV
c^T
a
b
a
T
F
a
c^F
b

(2) The folding line is parallel to an edge view—a normal plane.

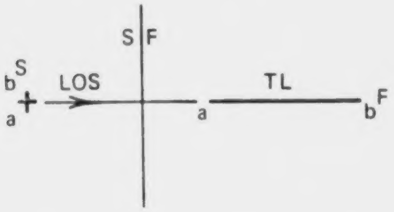

a
b
c^T
EV
T
F
b
TS
a
c^F

Information Sheet

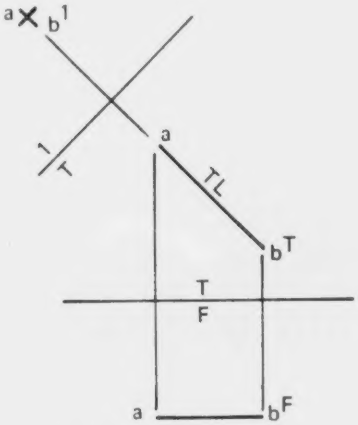
9. Guidelines for observing point views of lines and edge views of planes

a. Point views (PV) of lines are observed when:

(1) The line of sight is parallel to true length (TL) lines.

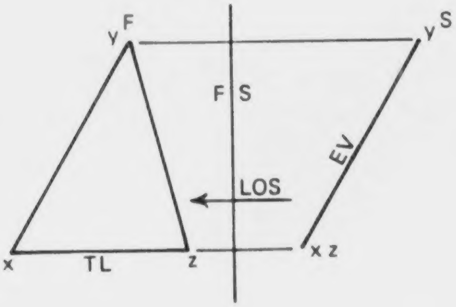

S | F
b^S
a
LOS
a
TL
b^F

(2) The folding line is perpendicular to the true length line.


a × b^1
1
T
a
TL
b^T
T
F
a
b^F

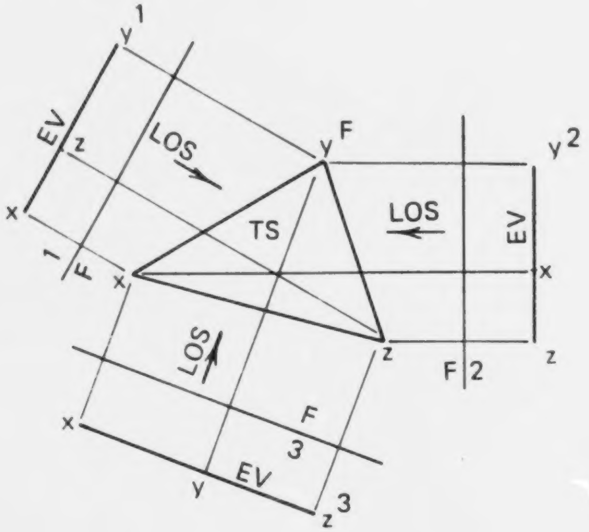
b. Edge views (EV) of planes are observed when:

(1) The line of sight is parallel to a true length line in the plane.


y^F
y^S
F | S
EV
LOS
x
TL
z
x z

Information Sheet

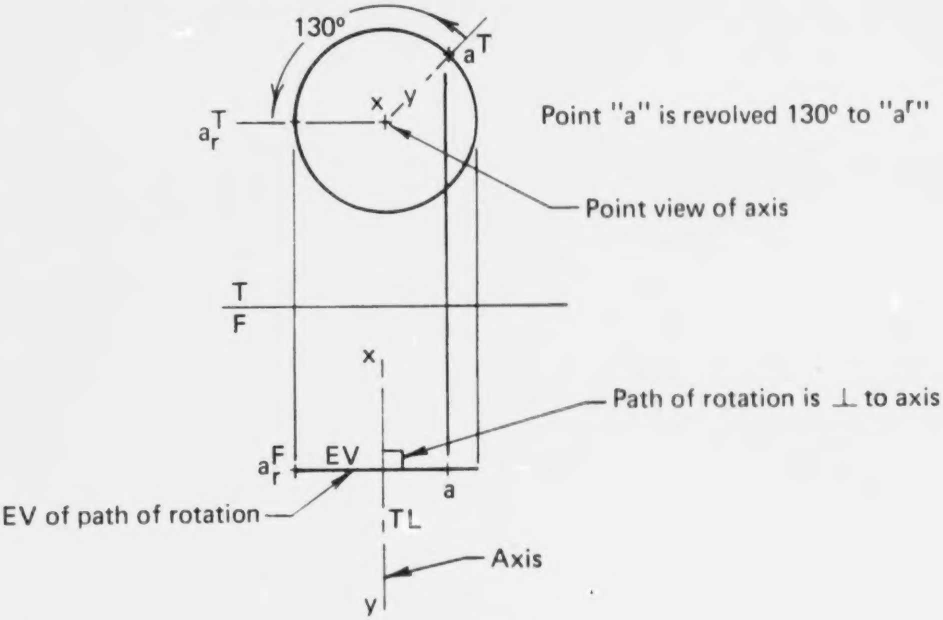
(2) The line of sight points to any view of a true size plane, and the results will be edge views.



y 1
EV
z
x
LOS
y F
y 2
TS
LOS
EV
x
1 F
x
x
LOS
z
F 2
z
x
F 3
y
EV
z 3

10. Rotation characteristics

a. The path of rotation of any point not on the axis appears as a circle in a view showing the axis of rotation as a point.



130°
a T
x y
a r T
Point "a" is revolved 130° to "a^r"
Point view of axis
T
F
x
Path of rotation is ⊥ to axis
a r F
EV
a
EV of path of rotation
TL
Axis
y

Note: Rotation is an easier way to find TL and TS.

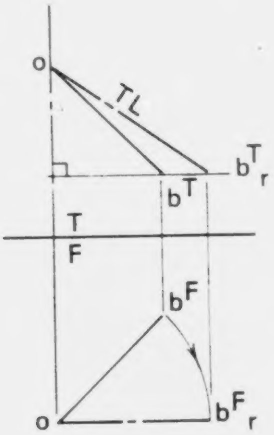
Information Sheet

b. The plane of the path of rotation of any point appears in edge view (EV) and perpendicular to the axis in a view showing the axis of rotation in true length.

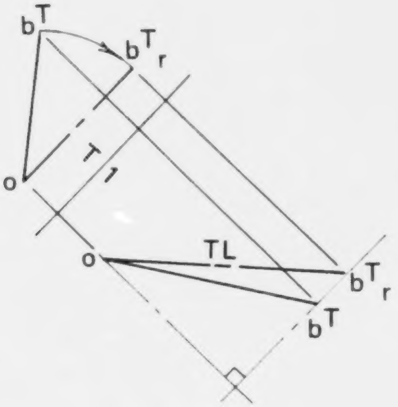
c. True lengths by rotation:

   (1) A line may be rotated until it is parallel to a principal plane.

   (2) The line is projected onto the adjacent plane.



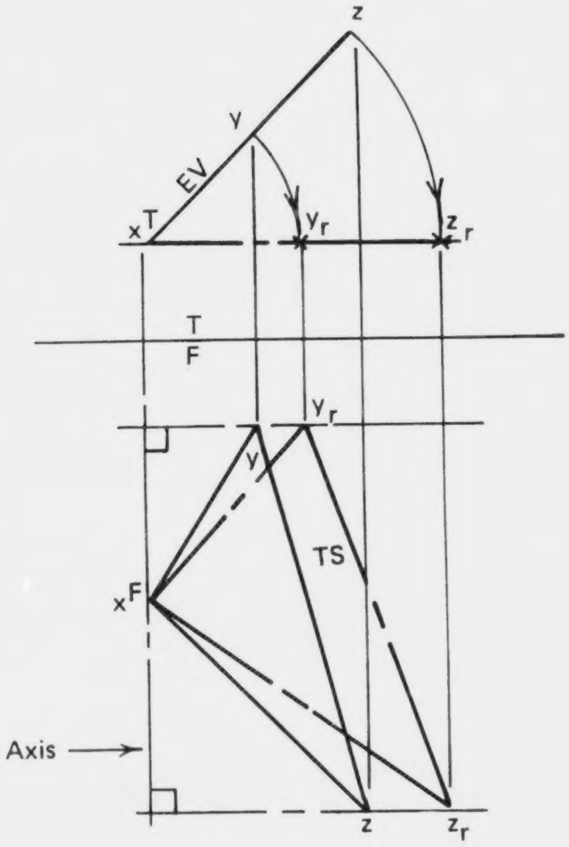
   (3) Since it is parallel to the folding line, it is in true length in the adjacent plane.



Information Sheet

d. True sizes by rotation:

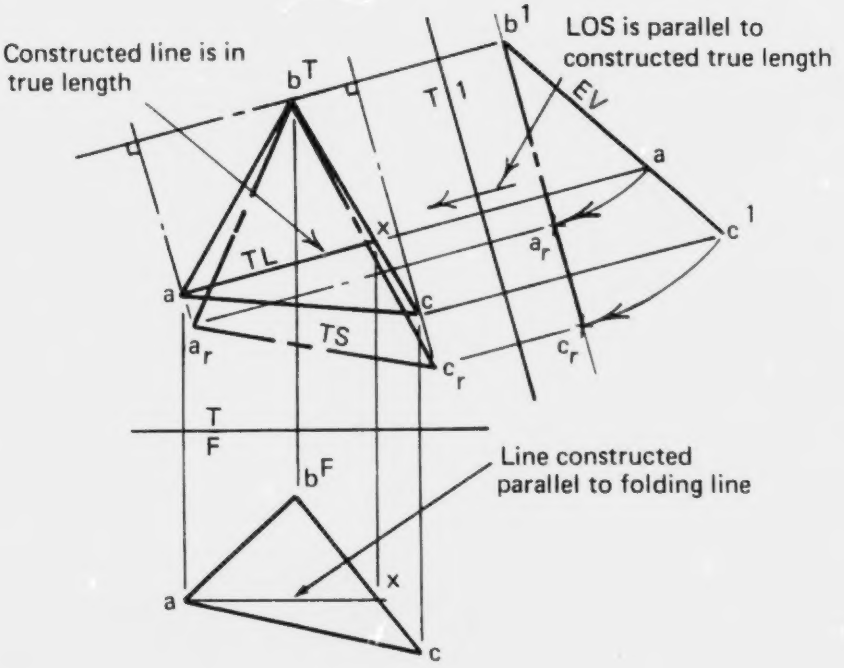
(1) An edge view may be rotated until it is parallel to an orthographic plane.


z
y
EV
x T
y r
z r
T
F
y r
y
TS
x F
Axis
z
z r

Information Sheet

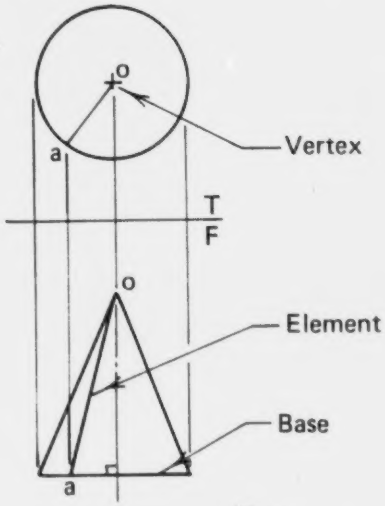
(2) The edge view is then projected onto the plane and s in true size.

Note: In this example, edge view is found by constructing horizontal line ax in front view and projecting TL line in top view.


Constructed line is in true length
b^T
b^1
LOS is parallel to constructed true length
EV
T
1
a
c^1
x
TL
a_r
a
c
a_r
TS
c_r
c_r
T
F
b^F
Line constructed parallel to folding line
x
a
c

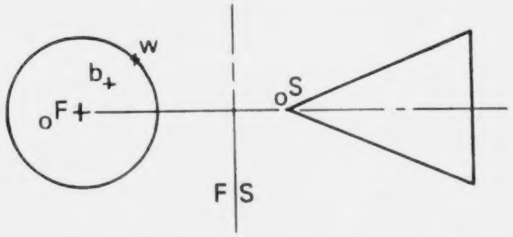
11. **Elements of single curved surfaces**

a. Cones—Vertex to base:

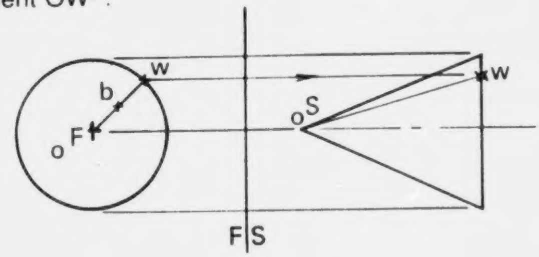

o
a
Vertex
T
F
o
Element
Base
a

Information Sheet

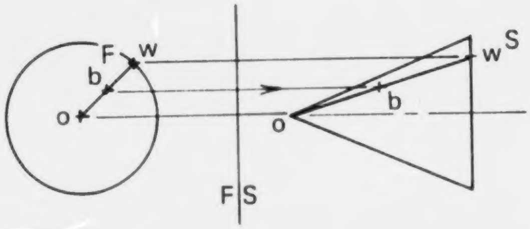
Example: Locate point b on surface of cone in side view.



(1) Project from vertex O^F through b to base of cone point W to make element OW^F.

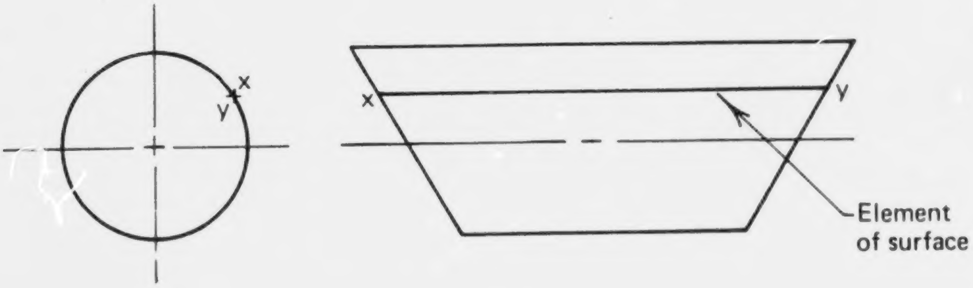


(2) Project point W to side view to base of cone W^S and connect O^S to W^S to make element OW^S.


F
w
b
o
w S
b
o
F S

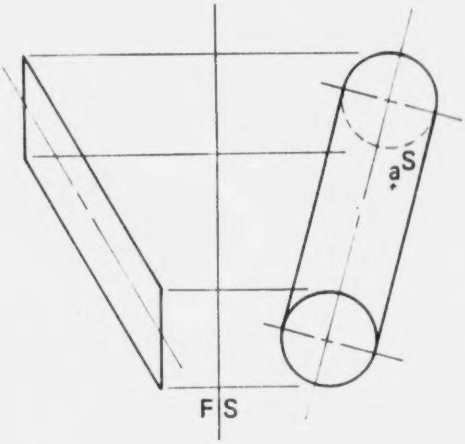
(3) Project point b^F to find answer at element OW^S.

b. Cylinders—Parallel to center:

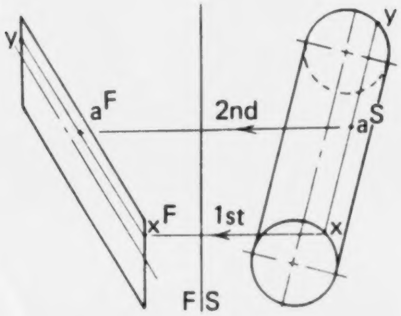

x
y
x
y
Element of surface

Information Sheet

Example: Locate point "a" on surface of cylinder.



(1) Project element xy through "a" intersecting circles in side view.



(2) Project intersection of X and Y to adjacent edge view of circles and connect to form element in front view.

Note: One line is all that is necessary because element is parallel to center of cylinder.

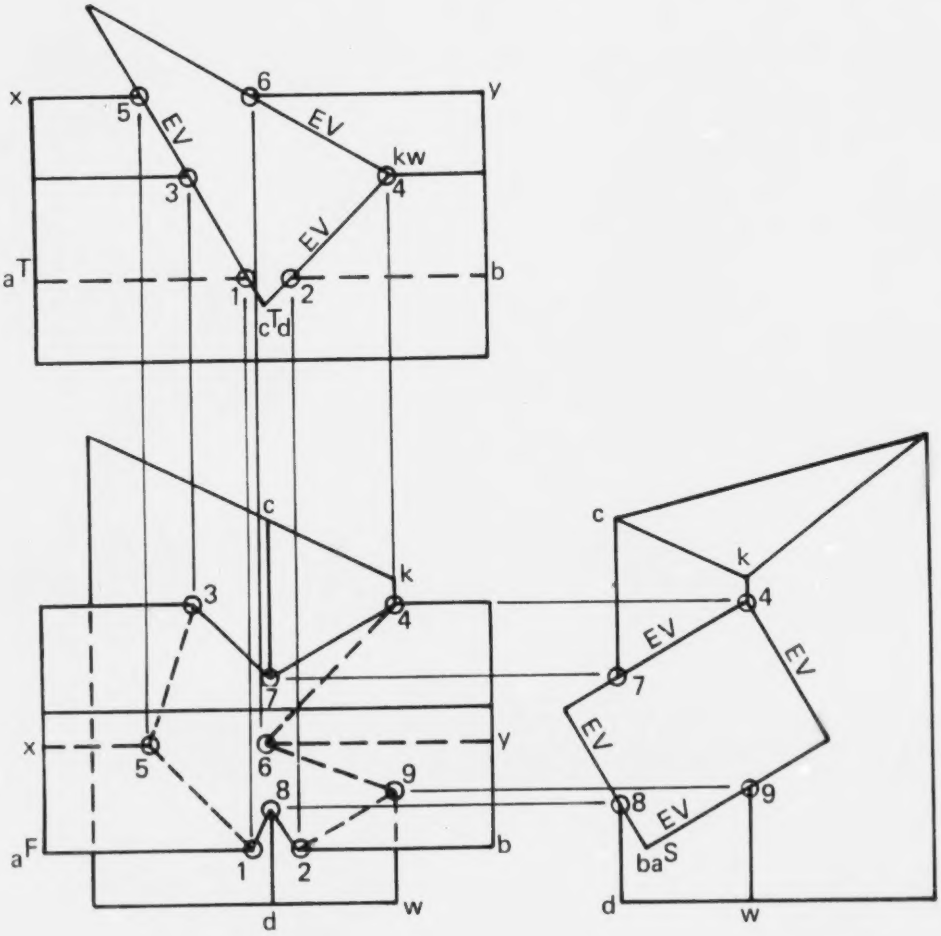
(3) Project point "a^S from side view" to find answer to problem at element XY^F in front view.

Information Sheet

12. Methods for finding intersections of surfaces

a. Edge view given:

Example:


x
y
5
6
EV
EV
kw
3
4
EV
a
T
b
1
2
c
T
d
c
k
3
4
7
x
y
5
6
8
9
a
F
b
1
2
d
w
c
k
4
EV
EV
7
EV
8
9
EV
ba
S
d
w

(1) When edge views are given, existing piercing points can be readily located and projected.

(2) Visibility requires logical thinking of the position of the line of sight and what is near the observer and what is far from the observer.

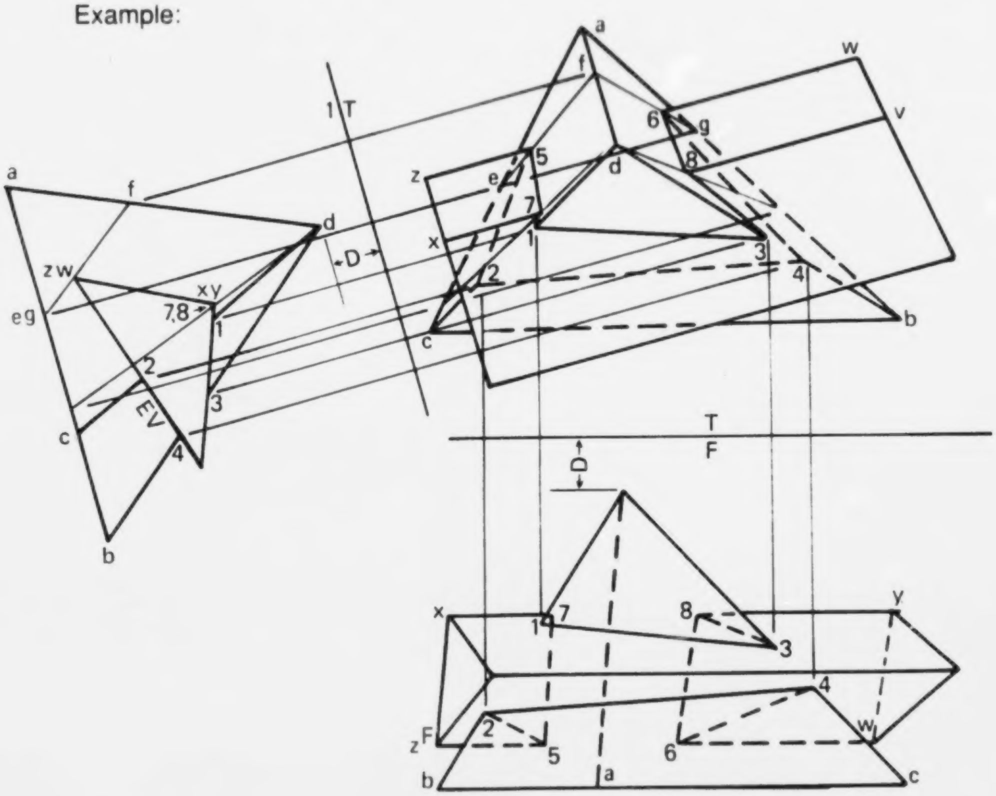
(3) Points 5 and 6 can be observed in top view where line xy intersects the two edge views.

Information Sheet

(4) Points 8 and 9 can be observed in the side view where the edges of the planes are intersected by cd and kw.

b. Auxiliary view method:

Example:


a
f
1
T
d
D
zw
xy
7,8
1
eg
2
EV
3
c
4
b
a
w
f
v
6
g
8
z
e
5
d
7
x
1
3
2
4
c
b
T
F
D
x
1
7
8
y
3
4
zF
2
5
6
w
b
a
c

(1) Construct an auxiliary view to give edges of surfaces so that line zw is in TL in top view, and LOS is parallel to TL to give edge views of the planes in the auxiliary view.

(2) When edges are constructed, piercing points may be readily located and projected.

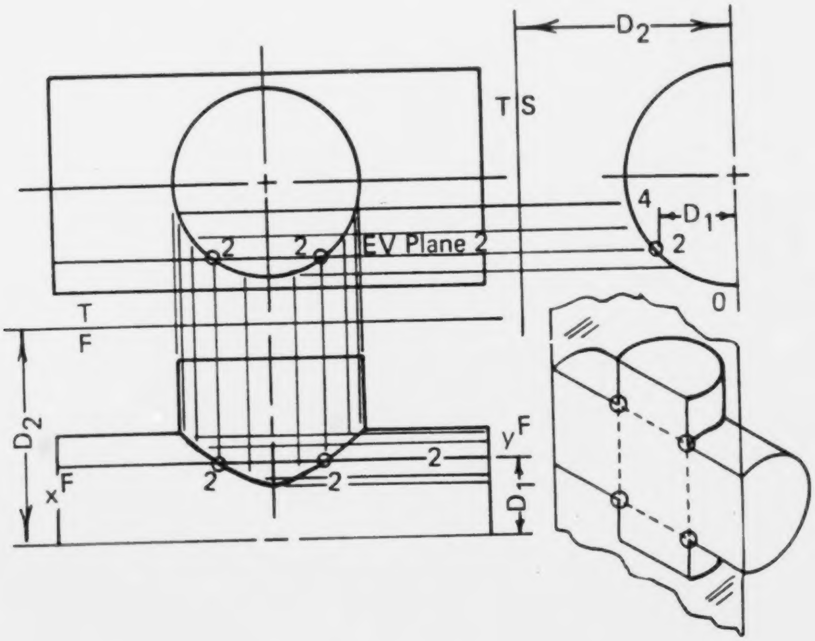
Note: the two-view method can be used to find additional piercing points.

(3) The two-view method of piercing points is used to find where line zw and line xy intersect the planes adc and adb.

Information Sheet

(4) Visibility requires logical thinking of the position of the line of sight and what is near the observer and what is far from the observer.

c. Cylinders intersecting:


D2
T
S
4
D1
2
2
2
EV Plane 2
0
T
F
D2
xF
yF
2
2
2
D1

(1) Locate elements on surface of cylinders.

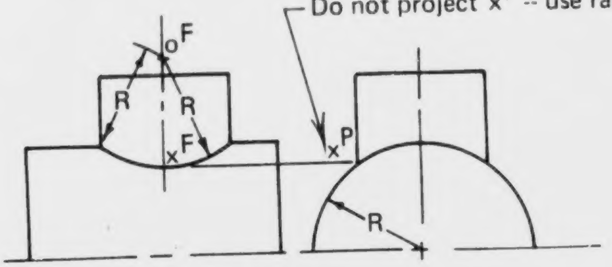
(2) Find their intersection.

(3) Use correct visibility.

d. Approximate intersections:

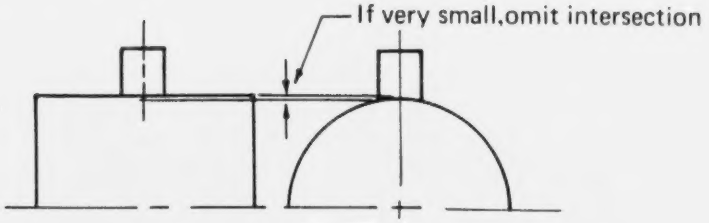
(1) For large diameters, use radius of larger cylinder.

Do not project x^F -- use radius of larger diameter



Information Sheet

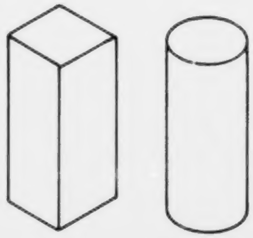
(2) For small diameters, ignore intersection.



13. General groups of developments and their characteristics

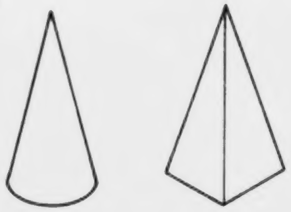
a. **Parallel line development**—The development of objects that can be developed because of parallel elements on their surfaces

Examples: Cylinders and prisms



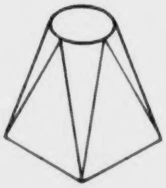
b. **Radial line development**—The development of objects that can be developed because of elements radiating from a single point or vertex

Examples: Cones and pyramids



c. **Triangulation**—A method of developing surfaces which cannot be developed by the parallel line or radial line methods

Examples: Transition pieces and hoppers



Information Sheet

14. Guidelines for making a bend allowance calculation

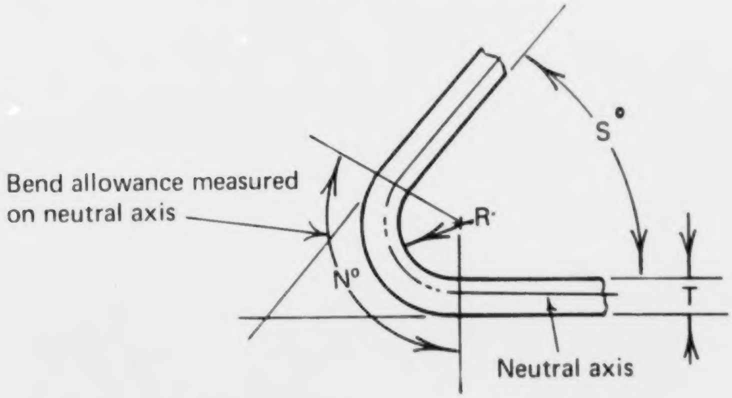
a. Calculate for materials thicker than .65mm (.16").

b. Start with the formula: BA = (.017453R + .0078T)N.

c. Identify elements of the bend:

BA = Bend Allowance
R = Radius of bend, IML
T = Metal thickness
N = Number of degrees in bend

d. Add and multiply as required to obtain result.


S°
Bend allowance measured on neutral axis
R
N°
T
Neutral axis

Example: If Radius = .75"
Thickness = .25", and
Number of degrees = 130°, then
BA = (.017453R + .0078T)N
BA = (.017453(.75) + .0078(.25))130°
BA = (.0130879 + .00195)130°
BA = .0150397(130) = 1.955161, round to 1.96
BA = 1.96

Sheet Metal Developments
Unit 9

Assignment Sheet 1—Label Points, Lines, and Planes In Views

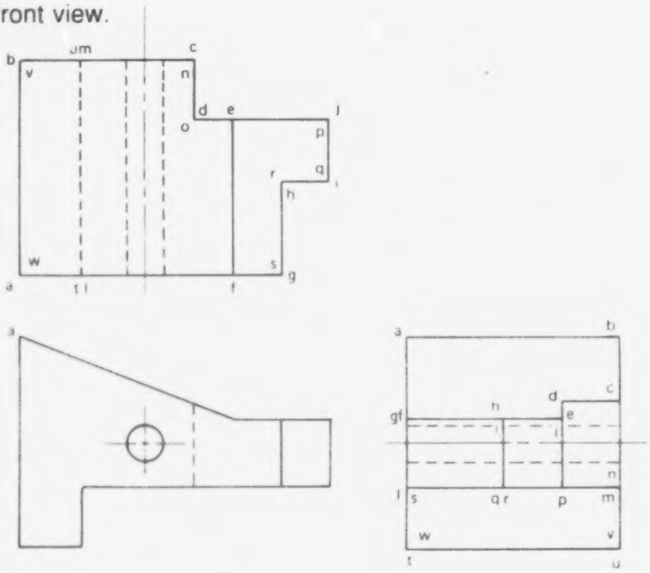
Name ______________________ Overall Rating __________

Evaluation criteria	**Rating**
Number of top and front views labeled	______
Number of lines labeled	______
Number of projected surfaces labeled	______

Directions: Refer to the Information Sheet as required for guidelines, then use the following drawings to label all points as indicated and answer the questions which follow each problem. Your instructor may request you to skip this assignment sheet and go directly to Assignment Sheet 3.

Problems:

A. Label points on front view.

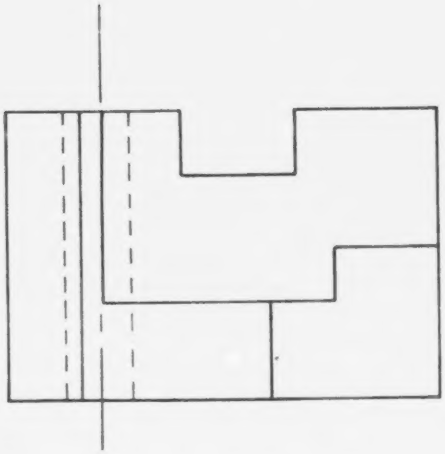


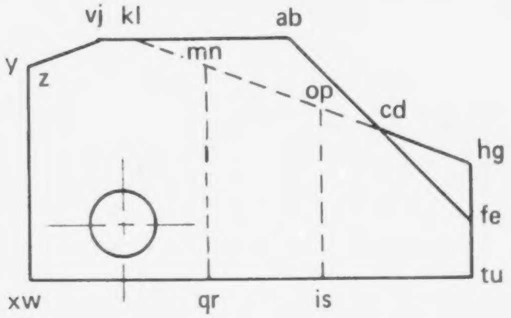
1. How many surfaces are normal? ______________________

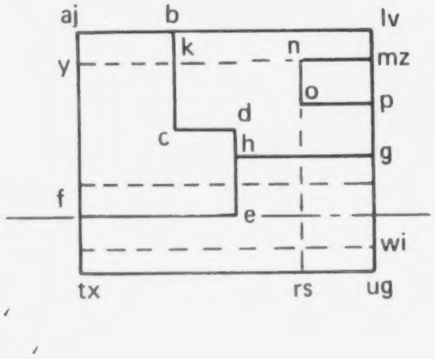
2. What surface is inclined? ______________________

Assignment Sheet 1

B. Label points on top view.




vj
kl
ab
y
z
mn
op
cd
hg
fe
tu
xw
qr
is


aj
b
lv
k
n
y
mz
o
p
d
c
h
g
f
e
wi
tx
rs
ug

1. What surfaces are inclined? ____________________

2. Do you see the similar surfaces of the inclined surfaces? ____________________

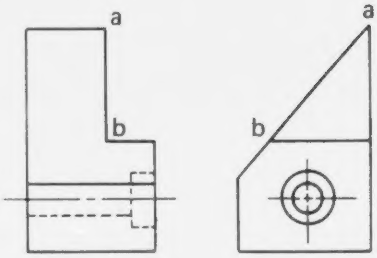
3. Is surface hgutfe normal, inclined, or oblique? ____________________

4. Is surface abcdef normal, inclined, or oblique? ____________________

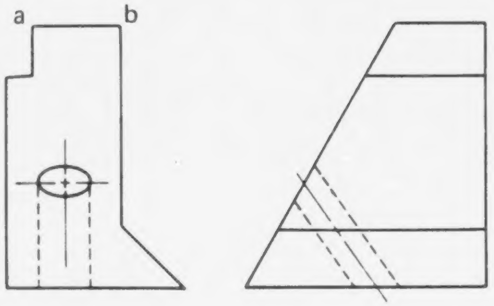
Assignment Sheet 1

C. Label lines indicated.

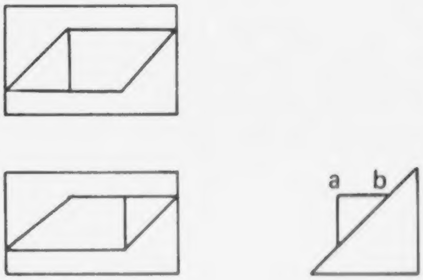
Example:



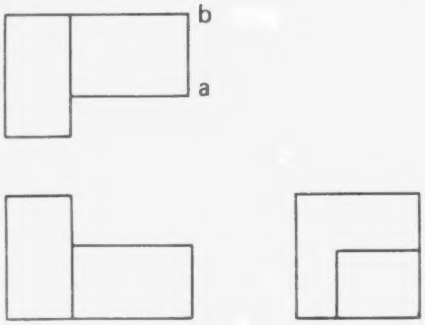
1.



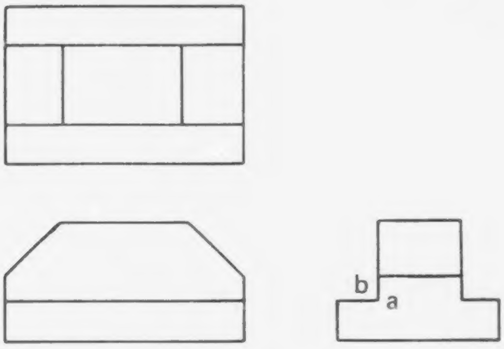
2.



3.

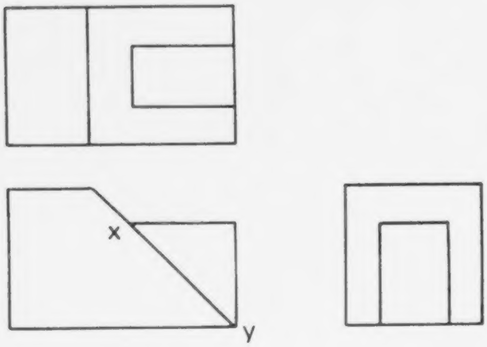


4.



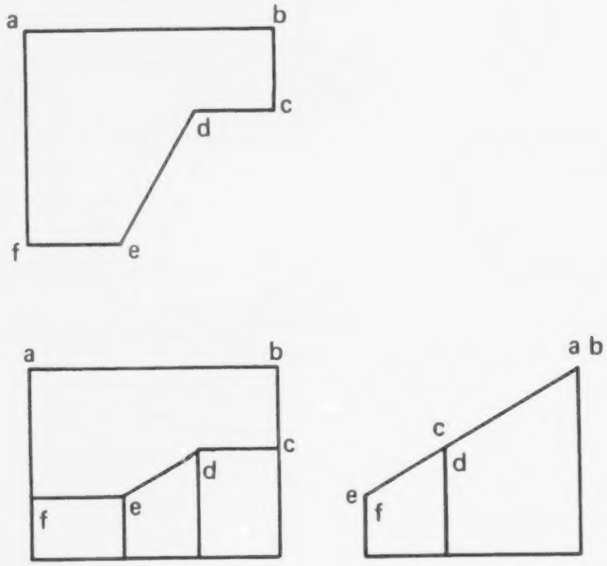
Assignment Sheet 1

5



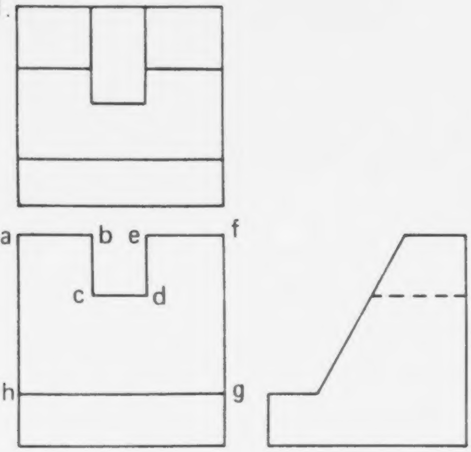
D. Label projected surfaces indicated.

Example:

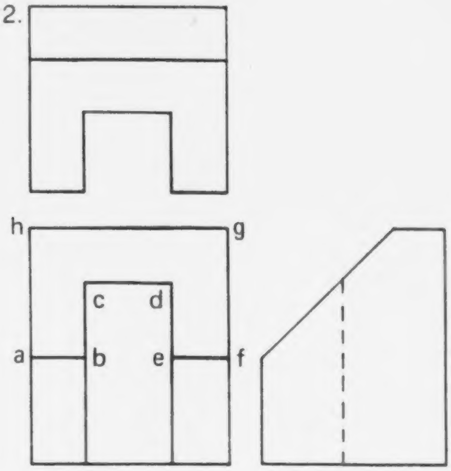

a
b
c
d
f
e
a
b
c
d
f
e
a b
c
d
e
f

Assignment Sheet 1

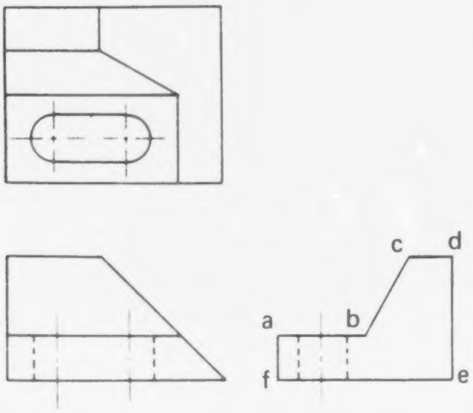
1.



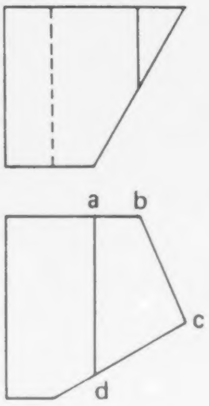
2.



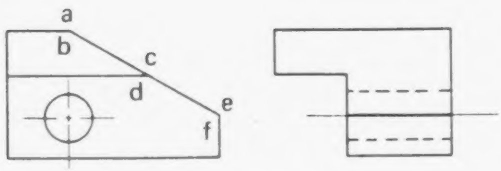
3.



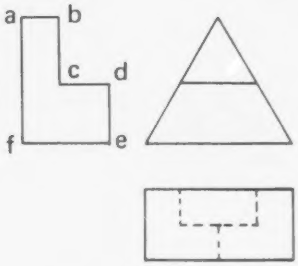
4.



5.

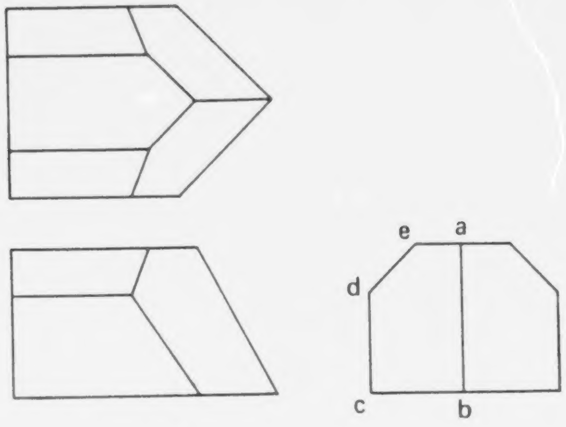


6.

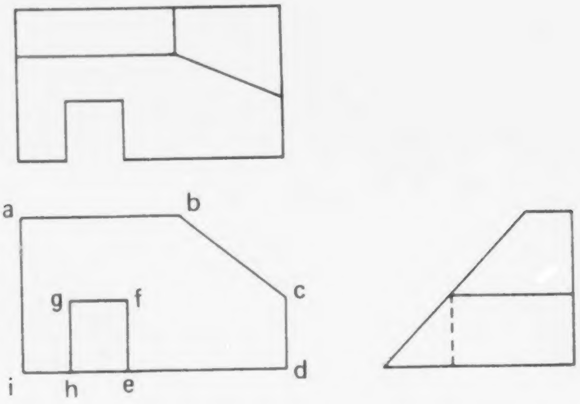


Assignment Sheet 1

7.



8.



Sheet Metal Developments
Unit 9

Assignment Sheet 2—Identify True Lengths And Types of Lines

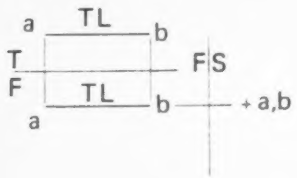
Name ______________________________ Overall Rating __________

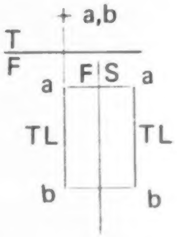
Evaluation criteria	**Rating**
True length lines identified	_____
Non true-length lines identified	_____
All tables complete and neat	_____

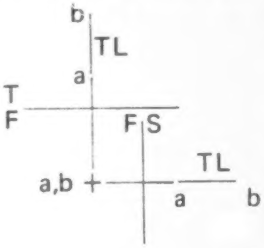
Directions: Identify true lengths and types of lines for the following problems. Use the following examples as guidelines, read the problems carefully, and complete the tables that follow. Your instructor may direct you to skip this assignment sheet and go directly to Assignment Sheet 3.

Examples:

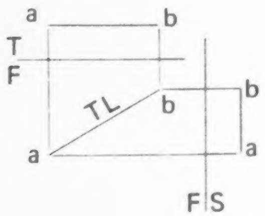
1. A normal line is in its true length in two views and a point view in a third view.

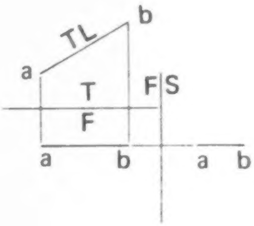

a
TL
b
T
F
F|S
TL
b
+ a,b
a

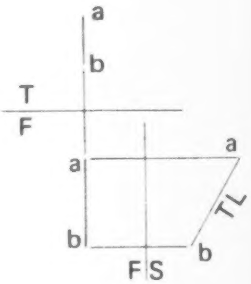

+ a,b
T
F
a
F|S
a
TL
TL
b
b


b
TL
a
T
F
F|S
TL
a,b +
a
b

2. An inclined line is in true length in one view and not in true length in the other two views.

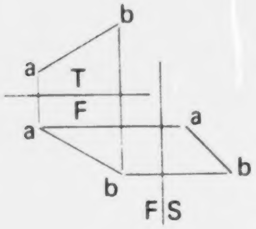

a
b
T
F
TL
b
b
a
a
F|S

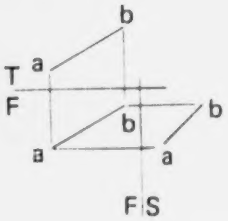

TL
b
a
T
F|S
F
a
b
a
b

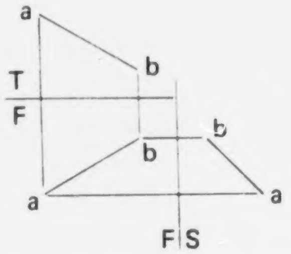

a
b
T
F
a
a
TL
b
b
F|S

Assignment Sheet 2

3. An oblique or skewed line is not in true length in any view.

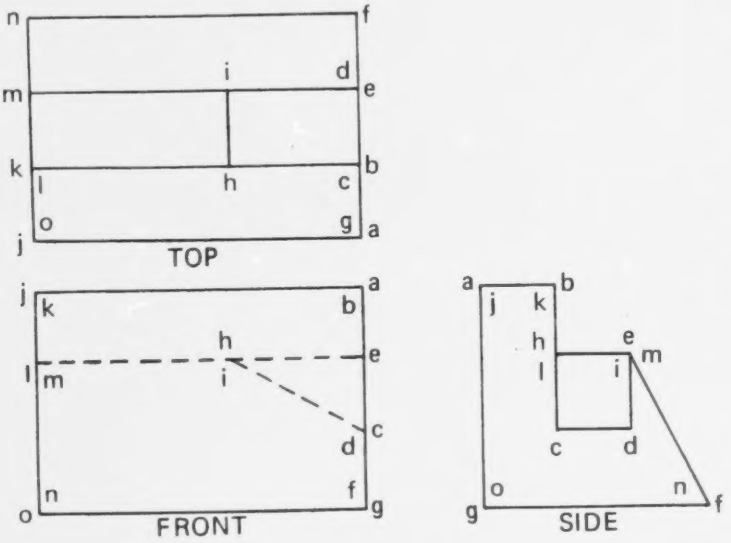

b
a
T
F
a
a
b
b
F S


b
T
a
F
b
b
a
a
F S


a
b
T
F
b
b
a
a
F S

Problems: Complete the tables by identifying all true length lines and non-true length lines, and indicate if line is normal, inclined, or oblique.

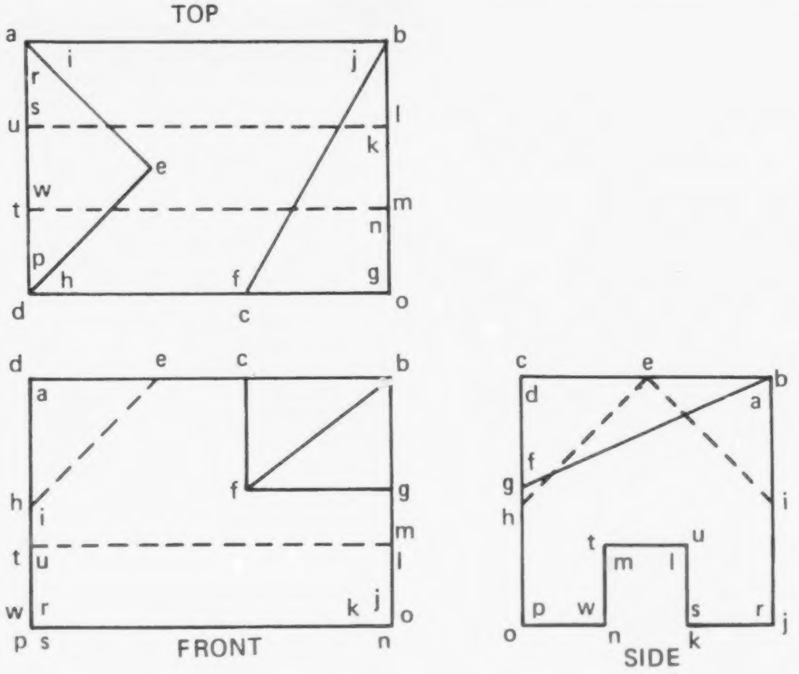
A.


n
f
i
d
m
e
k
b
l
h
c
o
g
j
a
TOP
j
a
k
b
h
e
l
m
i
c
d
n
f
o
g
FRONT
a
b
j
k
h
e
m
l
i
c
d
o
n
g
f
SIDE

Assignment Sheet 2

LINE	VIEW TL IS LOCATED	NON-TL	TYPE OF LINE		
			NORMAL	INCLINED	OBLIQUE
ab	Top & Side	—			
cd		—			
hc					
ef	Side				
nf	Top & Front	—			
oj		—	X		
gf	Top & Side	—			
hi		—			
id	Front	Top & Side			
eim		—			
lm		—			
og	Top & Front	—	X		

B.


TOP
a
b
i
j
r
s
u
l
k
e
w
t
m
n
p
h
f
g
d
c
o
d
e
c
b
a
h
f
g
i
m
t
u
l
w
r
k
j
o
p
s
FRONT
n
c
e
b
d
a
f
g
h
i
t
u
m
l
p
w
s
r
o
n
k
j
SIDE

Assignment Sheet 2

LINE	VIEW TL IS LOCATED	NON-TL	TYPE OF LINE		
			NORMAL	INCLINED	OBLIQUE
cb					
go	Front & Side	—			
he	—				X
fg	Front & Side	—			
fb	—	Top, Front, & Side			
ab		—			
gb		Top & Front			
hi	Top & Side	—			
tu		—			

Sheet Metal Developments
Unit 9

Assignment Sheet 3—Identify True Sizes And Types of Planes

Name ______________________________ Overall Rating ____________

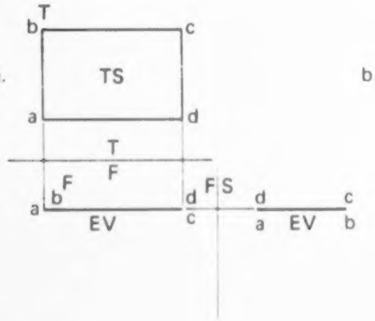
Evaluation criteria	Rating
True size planes identified as normal, inclined or oblique	______
Non true-size planes identified as normal, inclined or oblique	______
All tables complete and neat	______

Directions: Identify true sizes and types of planes for the following problems. Use the following examples as guidelines, read the problems carefully, and complete the tables that follow.

Examples:

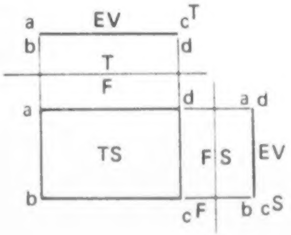
1. A normal plane is in true size in one view and in edge view in the other two views.

a.



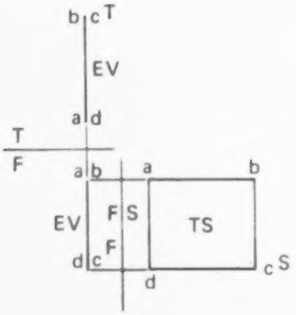
T
b
c
TS
a
d
T
F
F
a
b
d
c
F S
d
a
EV
c
b
EV

b.



a
EV
c T
b
d
T
F
a
d
a d
TS
F S
EV
b
c F
b c S

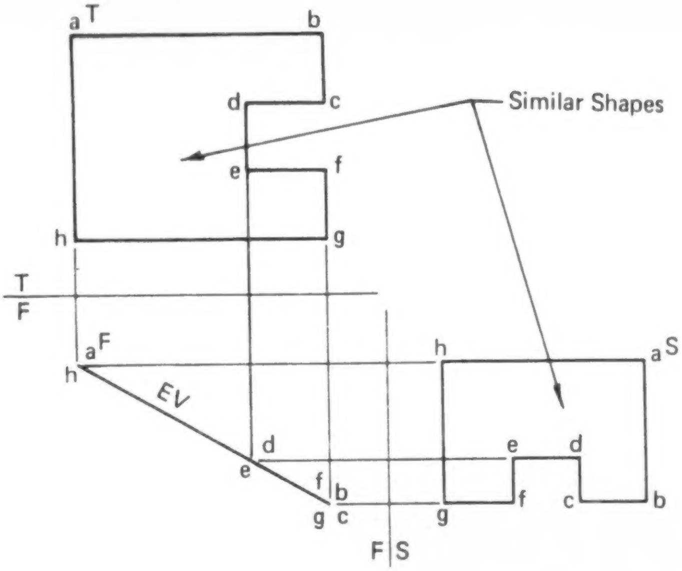
c.



b c T
EV
a d
T
F
a b
a
b
EV
F S
TS
F
d c
c S
d

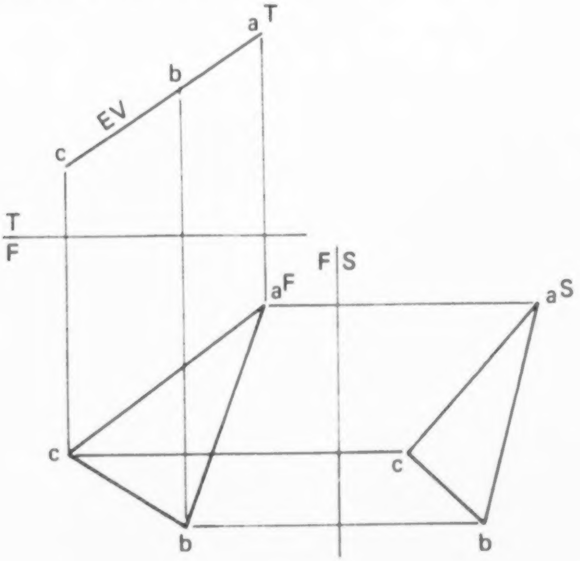
Assignment Sheet 3

2. An inclined plane is not in true size in any regular view but can be observed as two similar surfaces in two views and as an edge in the other view.


a T
b
d
c
Similar Shapes
e
f
h
g
T
F
a F
h
EV
d
e
f
b
g
c
F | S
h
a S
e
d
g
f
c
b
g

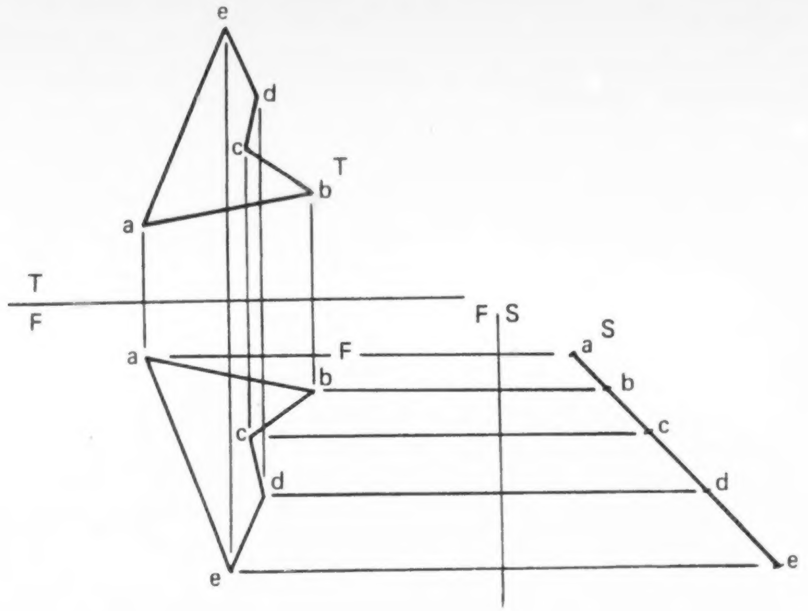
a.

Note: Observe the similar surface with the same number of points and lines. The similar surfaces are not in true size.


a T
b
EV
c
T
F
F | S
a F
a S
c
c
b
b

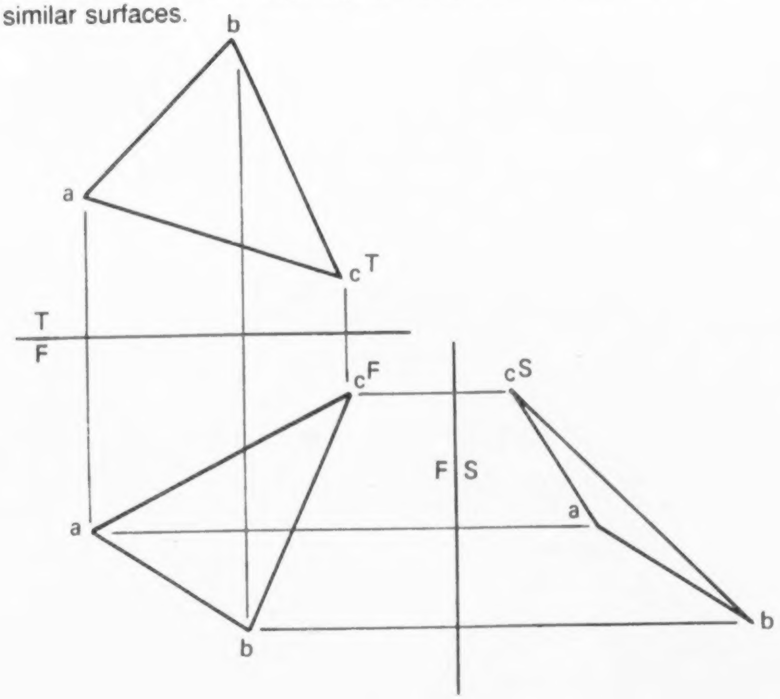
b.

Assignment Sheet 3


e
d
c
b
T
a
T
F
F
S
a
S
a
F
b
b
c
c
d
d
e
e

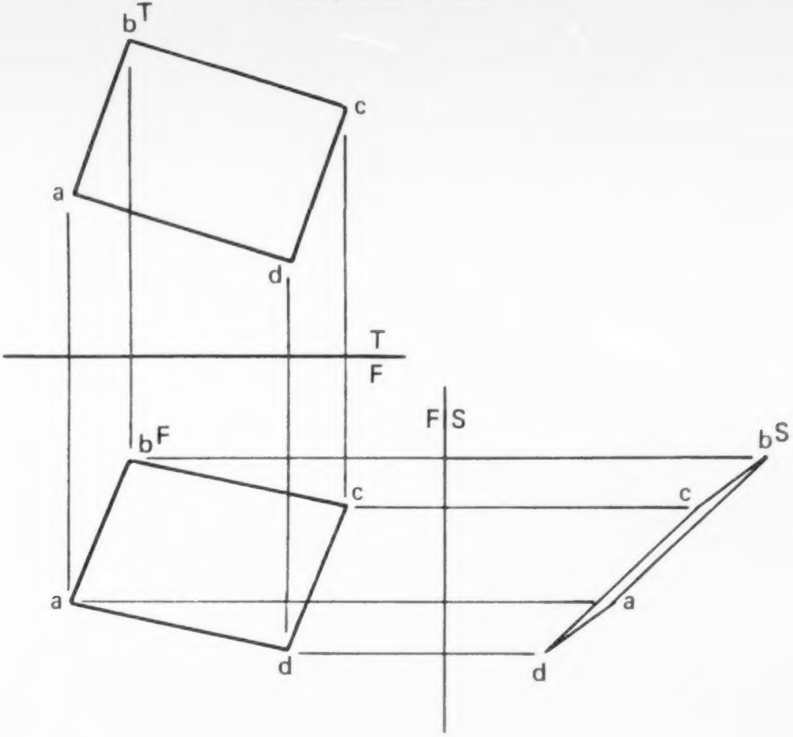
c.

3. An oblique plane is not in true size in any regular view; it can be observed in all three views as similar surfaces.


b
a
c
T
T
F
c
F
c
S
F
S
a
a
b
b

a.

Assignment Sheet 3

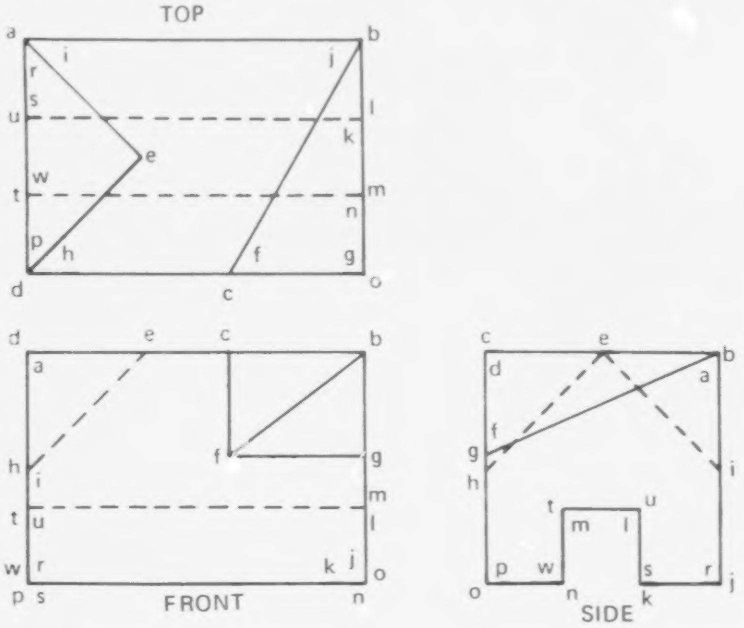

b^T
c
a
d
T
F
F|S
b^F
c
a
d
b^S
c
a
d

Note: Observe similar surfaces in all three views.

Assignment Sheet 3

Problems: Complete the tables by identifying all true size (TS) planes and non-true size planes, and indicate if plane is normal, inclined, or oblique.

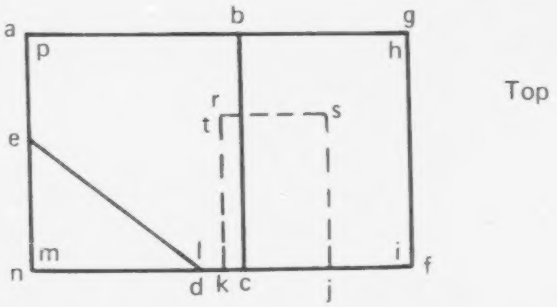
A.

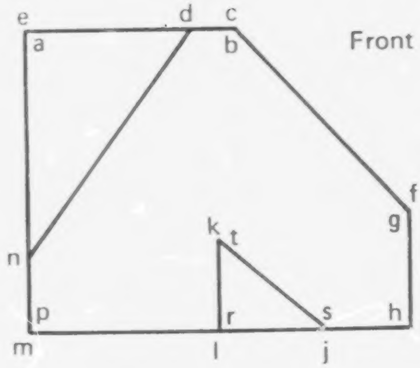

TOP
a
b
i
j
r
s
u
l
k
e
w
t
m
n
p
h
f
g
d
c
o
d
e
c
b
a
h
f
g
i
m
t
u
l
w
r
k
j
o
p
s
n
FRONT
c
e
b
d
a
f
g
h
i
t
u
m
l
p
w
s
r
o
n
k
j
SIDE

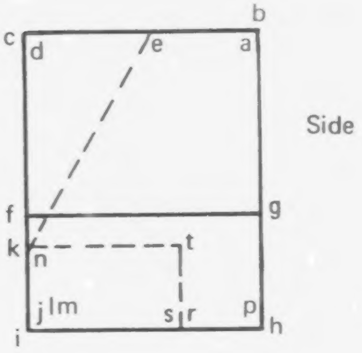
PLANE	VIEW TS IS LOCATED	VIEW NON-TS IS LOCATED	VIEW EDGE VIEW IS LOCATED	TYPE OF LINE		
				NORMAL	INCLINED	OBLIQUE
cbf	—		Top			
abcde	Top	—	Front & Side			
deh	—				X	
tmlu	Top	—	Top & Side			
bfg	—	Top & Front				

Assignment Sheet 3

B.


a
b
g
p
h
Top
r
t
s
e
m
l
i
n
f
d
k
c
j


e
d
c
a
b
Front
f
g
k
t
n
p
r
s
h
i
m
l
j


b
c
d
e
a
Side
f
g
k
t
n
j
l m
s
r
p
i
h

PLANE	VIEW TS IS LOCATED	VIEW NON-TS IS LOCATED	VIEW EDGE VIEW IS LOCATED	TYPE OF LINE		
				NORMAL	INCLINED	OBLIQUE
abcde		—	Front & Side			
bgfc	—	Top & Side	Front			
rst		—		X		
mpni	Top	—	Front & Side			
end	—				X	

Sheet Metal Developments
Unit 9

Assignment Sheet 4—Construct True Length Lines And True Size Planes Using Auxiliary Views

Name ______________________________ Overall Rating __________

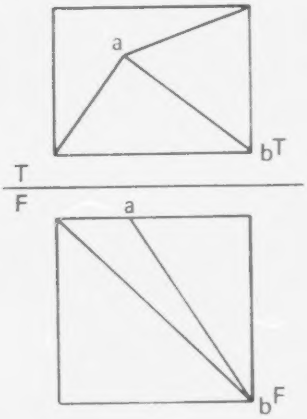
Evaluation criteria	Rating
True length of lines constructed	_____
True sizes of planes constructed	_____
Points properly labeled	_____

Directions: When a line is oblique to any principal view, an auxiliary view is required to find the true length. When a plane is inclined or oblique to the principal view, an auxiliary view is required to find the true size. Construct true lengths of lines and true sizes of planes and label the points.

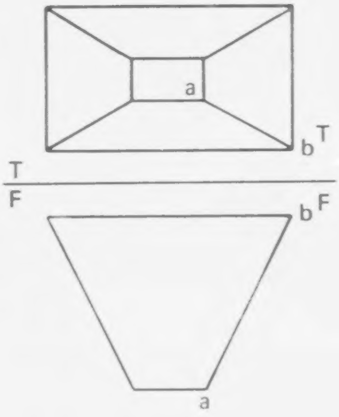
Problems:

A. Construct true lengths of the lines marked AB below using auxiliary view method. Label the points, and label the true length lines with TL.

1.

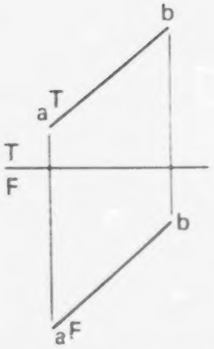


2. (Sheet metal)

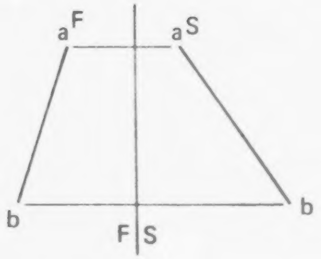


Assignment Sheet 4

3.

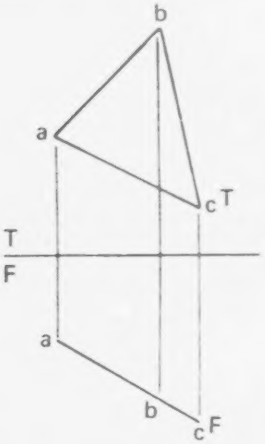


4.

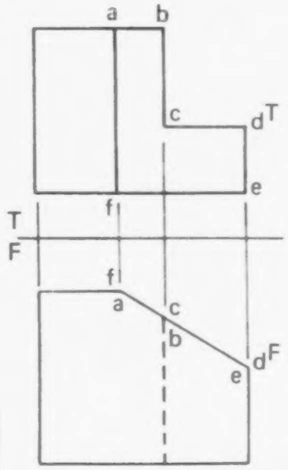


B. Construct true sizes of planes marked below using auxiliary views. Label the points, and label the true size with TS.

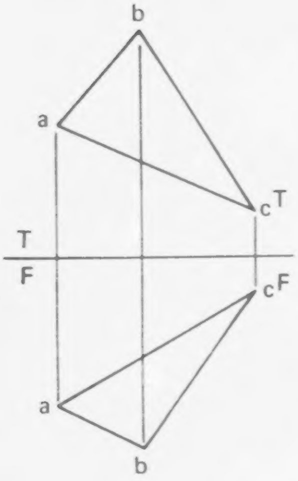
1.


b
a
c T
T
F
a
b
c F

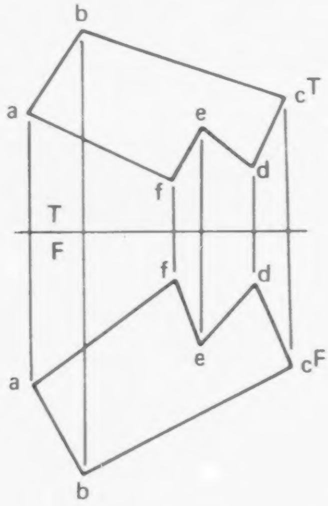
2.


a
b
c
d T
e
f
T
F
f
a
c
b
d F
e

3.


b
a
c T
T
F
c F
a
b

4.


b
a
c T
e
f
d
T
F
f
d
e
c F
a
b

Sheet Metal Developments
Unit 9

Assignment Sheet 5—Construct True Lengths Of Lines By Rotation

Name ________________________ Overall Rating __________

Evaluation criteria	**Rating**
True length of views constructed	______
True length of planes constructed	______
Points properly projected	______

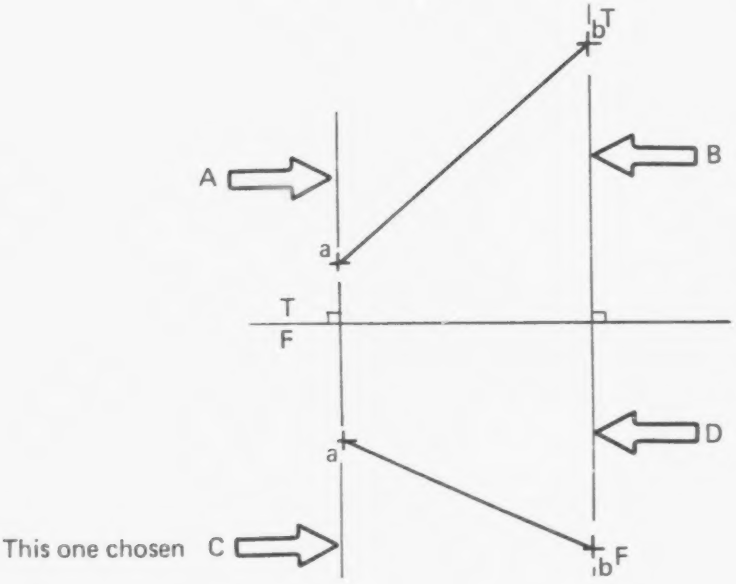
Introduction: In your previous study of orthographic projection and auxiliary views, the related principal views of an object are found by changing the position of the observer. This is the same as saying change the position of the line of sight. Different views of an object can also be obtained by rotating the object while the observer (LOS) stays stationary. This is the same as a fixed viewing direction. Rotation eliminates some of the auxiliary views previously needed. Rotation also adds the problem of confusion from overlapping views. This confusion can be reduced by using different colored pencils, by using overlays, or as in the case of developments, by using true length diagrams.

Directions: Construct true lengths of lines by rotation as outlined in the procedure of the following example.

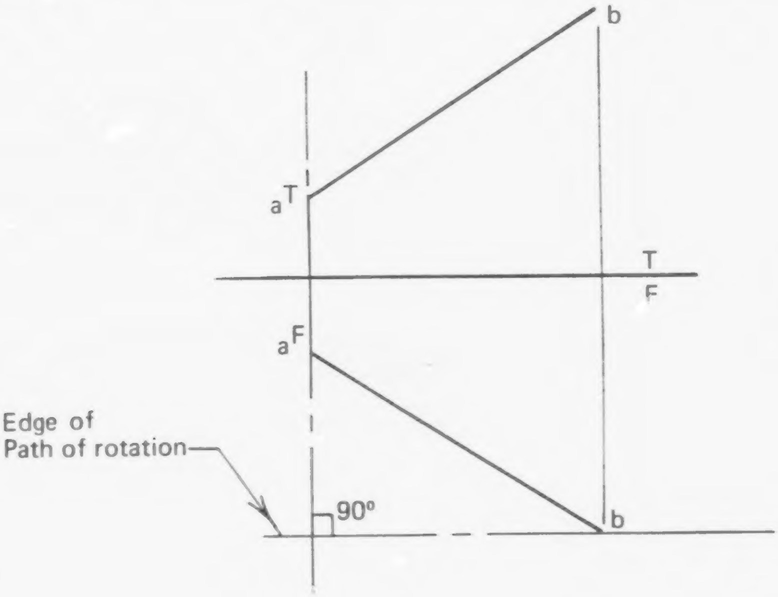
Example:

1. Select axis of rotation.
    a. Any one of the following could be chosen: A, B, C, or D; it must be perpendicular to the folding line.
    b. Your choice depends on what view you want TL in and what point you want rotated.
    c. In this example, axis "C" was chosen so TL will be in front view.

Assignment Sheet 5

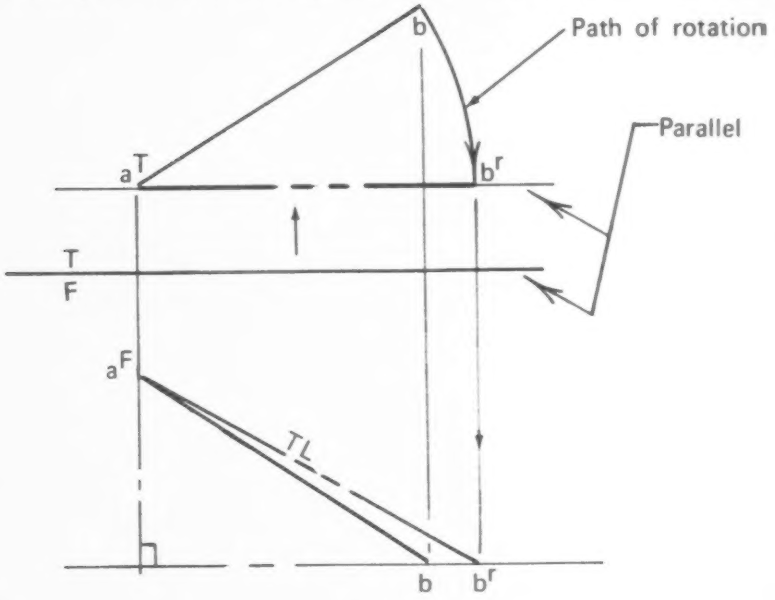

b
T
A
B
a
T
F
D
a
This one chosen
C
b
F

2. Complete path of rotation perpendicular to axis through the point to be rotated.


b
a
T
T
F
a
F
Edge of
Path of rotation
90°
b

Assignment Sheet 5

3. In the adjacent view, construct a path of rotation from "b" to a position where "ab" will be parallel to the folding line; mark new point b′ and project to adjacent view.

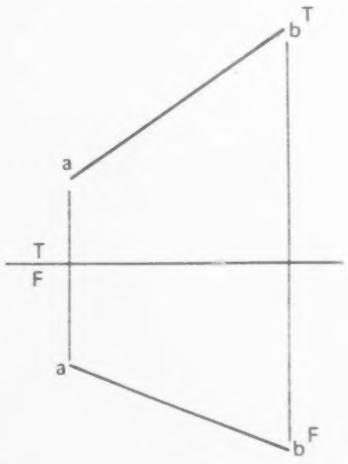

b
Path of rotation
Parallel
a^T
b^r
T
F
a^F
TL
b
b^r

4. Connect "a" to the new b′ in the front view; mark it TL.

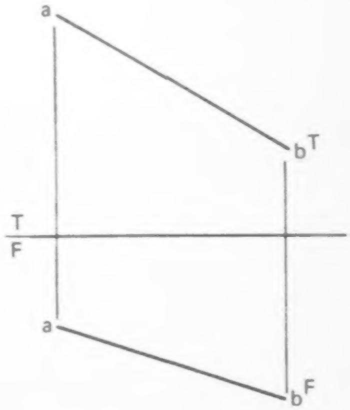
Note: Line ab′ is in TL because it has been rotated parallel to the front plane or perpendicular to the LOS.

Problems:

A. Find TL in front view.

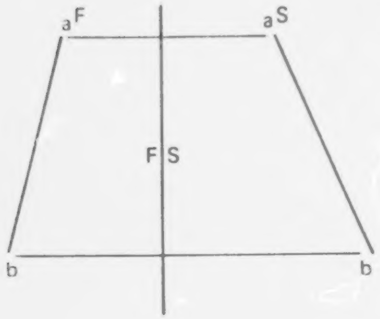


B. Find TL in top view.

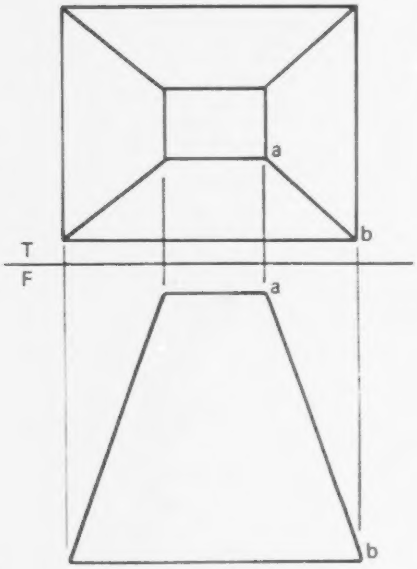


Assignment Sheet 5

C. Find TL in side view.

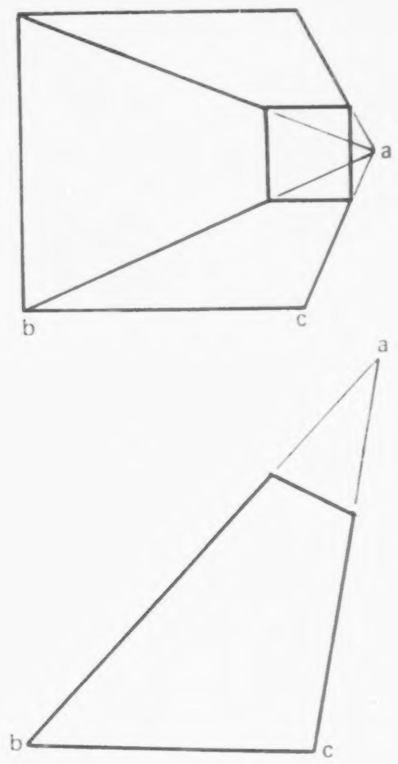


D. Find TL in front view.



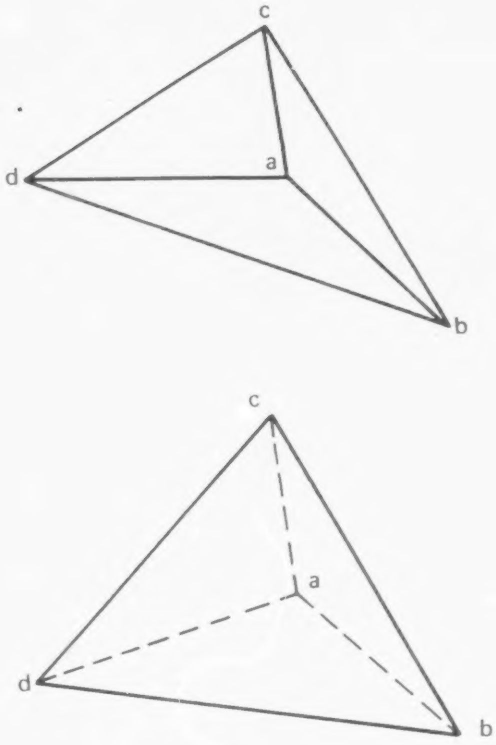
Assignment Sheet 5

E. Find TL of ab and ac.



TL of ab = ______________
TL of ac = ______________

F. Find Tl of ab, ac, and ad.



TL of ab = ______________
TL of ac = ______________
TL of ad = ______________

Sheet Metal Developments
Unit 9

Assignment Sheet 6—Construct True Sizes of Planes By Rotation

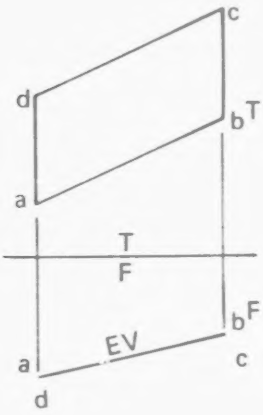
Name ______________________________ Overall Rating __________

Evaluation criteria	Rating
True sizes of planes constructed	______
Rotation points properly selected	______

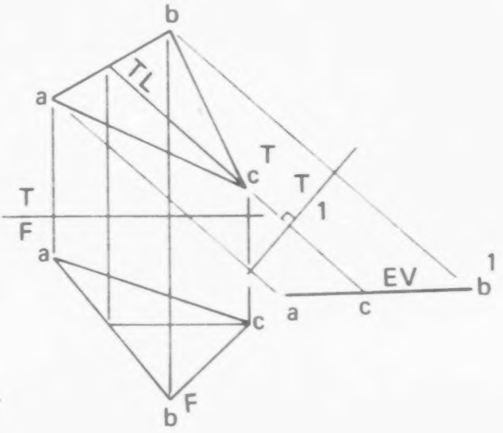
Directions: Construct true sizes of planes by rotation using the procedures presented in the following examples.

Example:

1. Construct or identify edge view of plane as shown in a and b.



a.

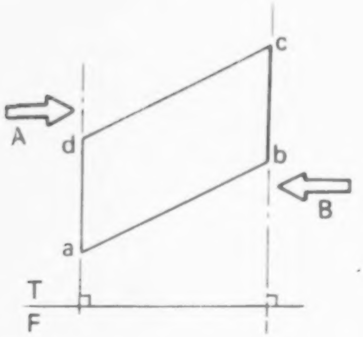


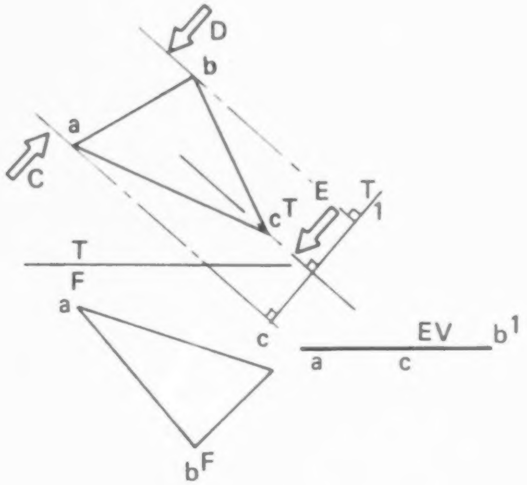
b.

Assignment Sheet 6

2. Select axis of rotation.

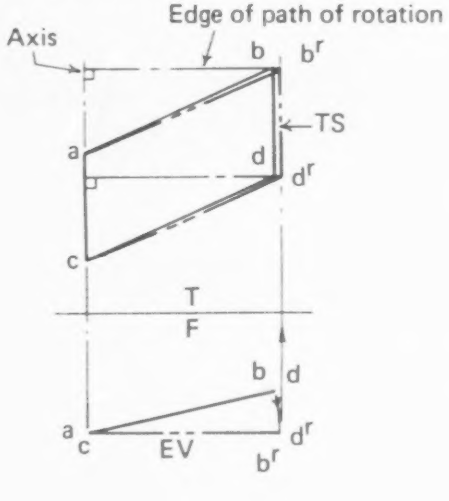
   a. Any axis could be chosen, but it must be perpendicular to the folding line next to the edge view.

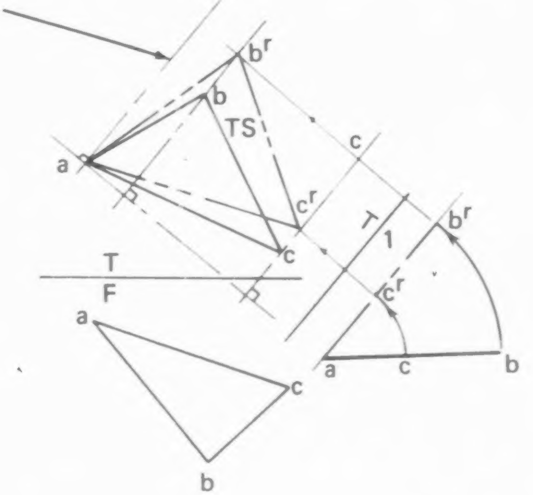



D
b
a
C
c^T
E
T
1
T
F
a
c
EV
b^1
a
c
b^F

   b. Your choice depends on what points you want to rotate.

3. Construct the edge of the path of rotation perpendicular to axis through the points to be rotated.


Edge of path of rotation
Axis
b
b^r
TS
a
d
d^r
c
T
F
b
d
a
c
EV
b^r
d^r


b^r
b
TS
a
c
c^r
c
T
1
b^r
c^r
T
F
a
a
c
b
c
b

a. b.

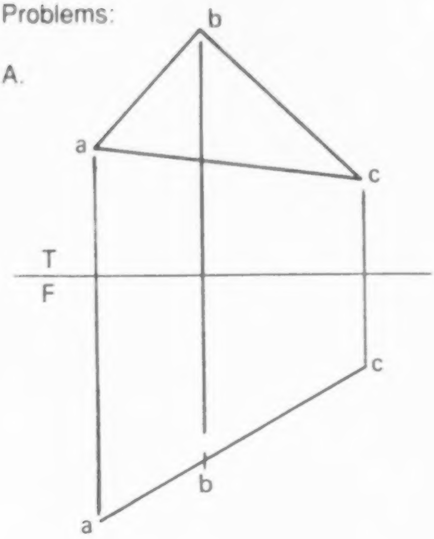
Assignment Sheet 6

4. In the edge view, construct a path of rotation from center point to a position parallel to folding line, and mark new point.

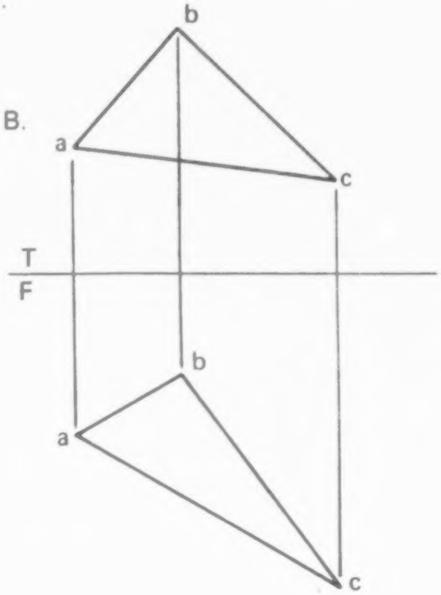
5. Connect all points forming true size of plane.

Problems:

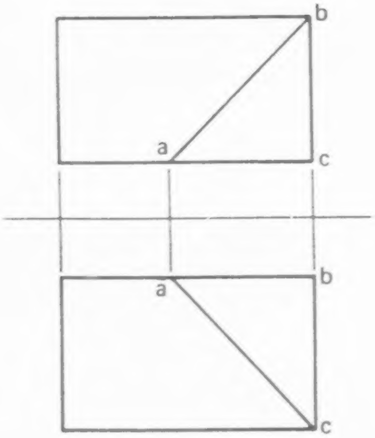
A.



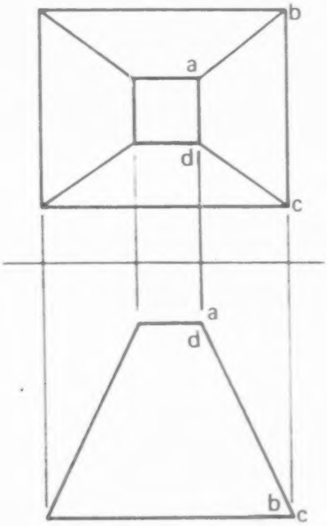
B.



C.

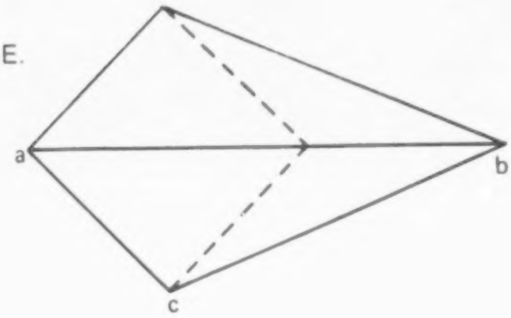


D.

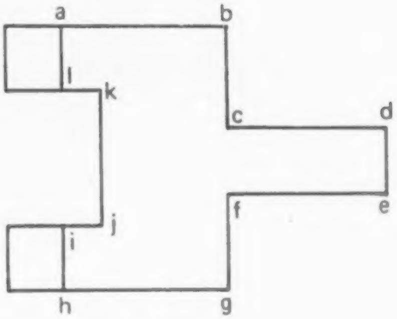


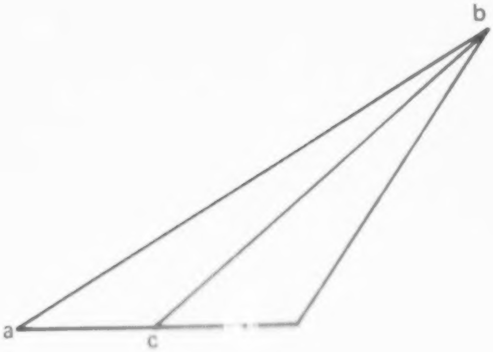
Assignment Sheet 6

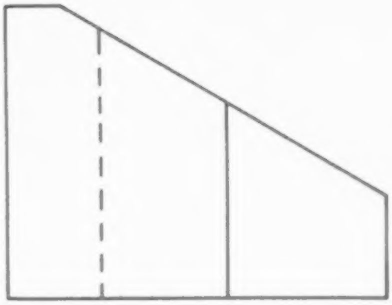
E.



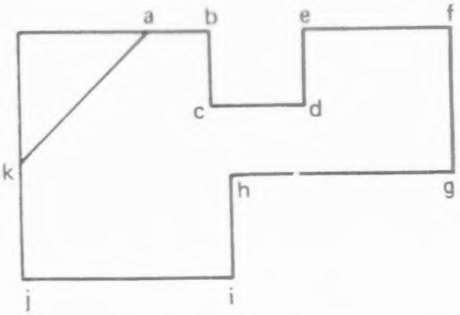
F.


a
b
l
k
c
d
j
i
f
e
h
g

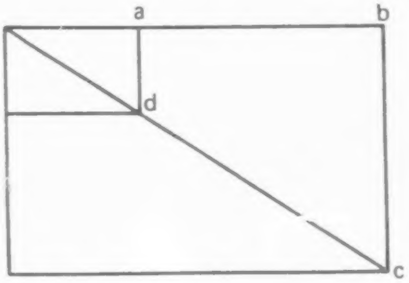


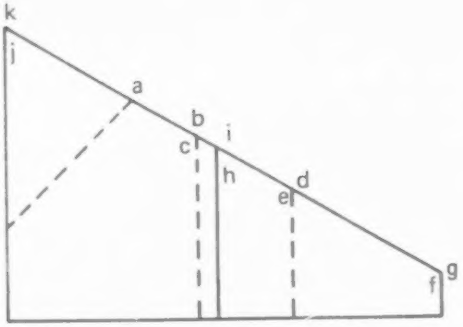


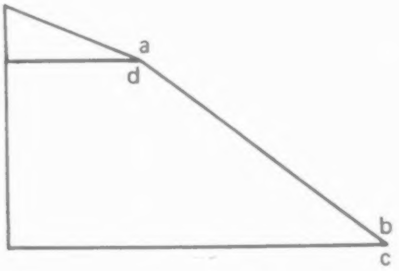
G.


a
b
e
f
c
d
k
h
g
j
i

H.




k
j
a
b
i
c
h
d
e
g
f



Sheet Metal Developments
Unit 9

Assignment Sheet 7—Locate Elements Of Single Curved Surfaces

Name ______________________________ Overall Rating __________

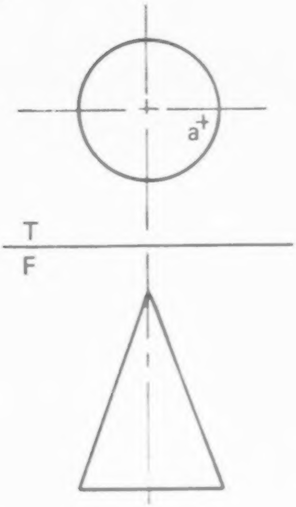
Evaluation criteria	**Rating**
Location of point a in cones	______
Location of point a in cylinders	______
Bonus points for alternate answers	______

Directions: Locate elements on the surfaces of the following single curved surfaces to locate point a in the views of cones and cylinders. There are two possible answers for A3 and A4, and two possible answers for all items in B. For bonus points, complete both answers.

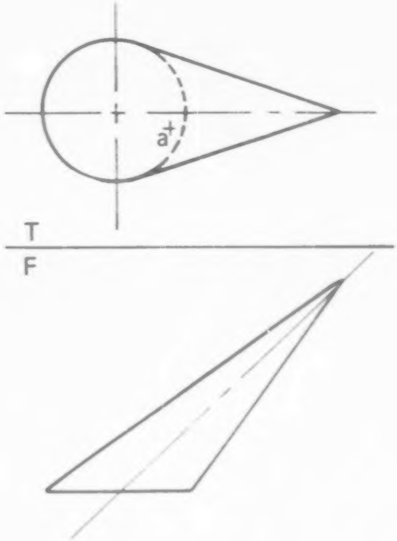
Problems:

A. Cones

1.

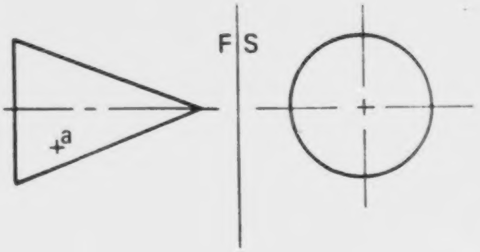


2.

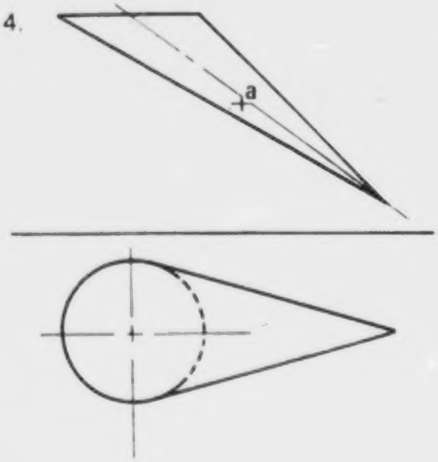


Assignment Sheet 7

3.



4.

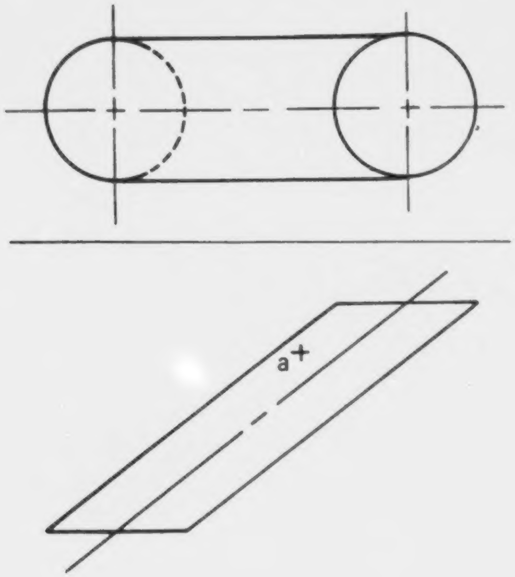


Note: Two answers are possible for problems 3 and 4.

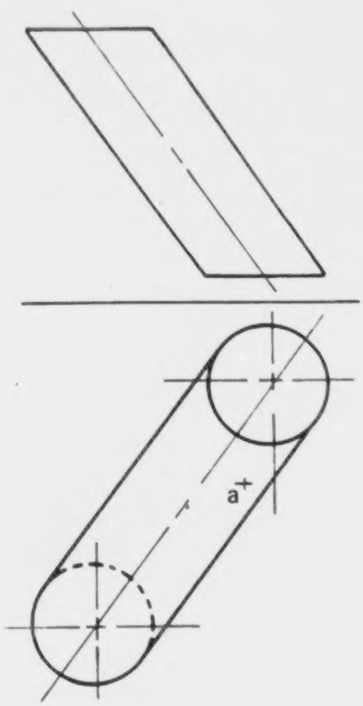
B. Cylinders

Note: Two solutions are possible for each of these problems.

1.

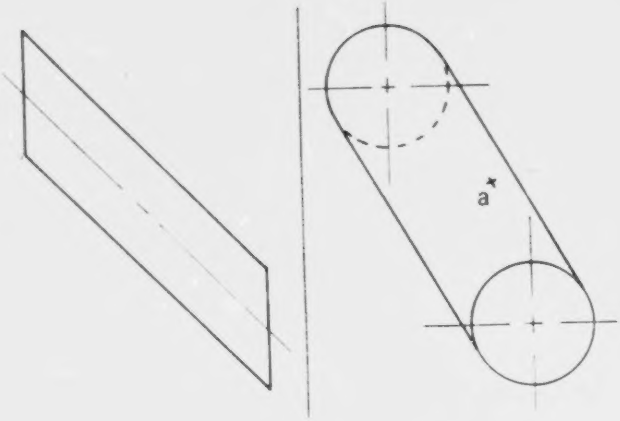


2.

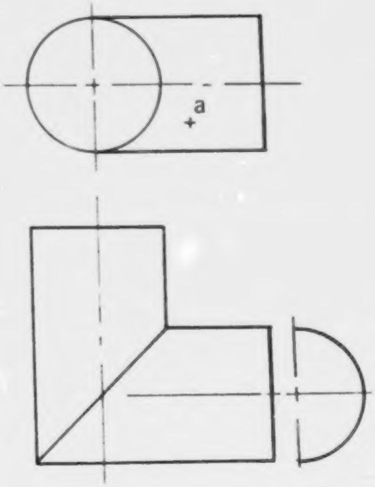


Assignment Sheet 7

3.



4.



Sheet Metal Developments
Unit 9

Assignment Sheet 8—Construct Intersections Of Surfaces

Name ______________________________ Overall Rating __________

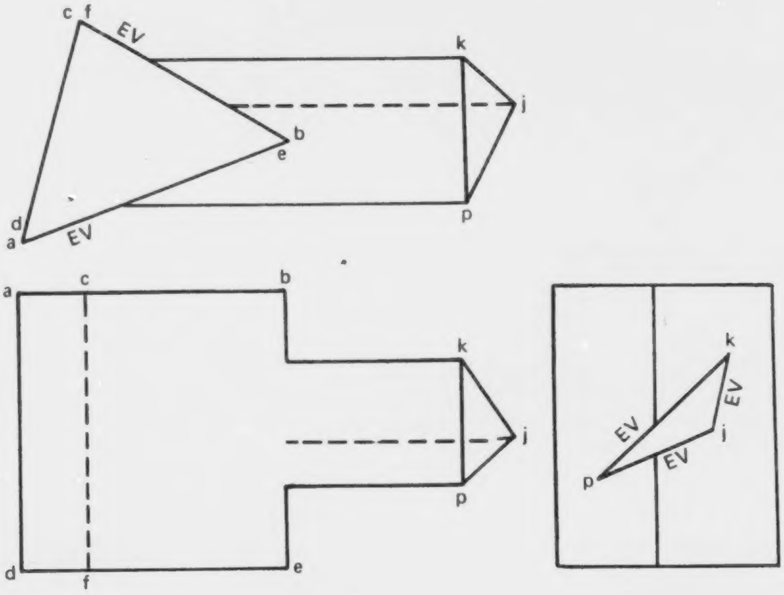
Evaluation criteria	Rating
Number of lines of intersection constructed	______
Piercing points properly circled	______
Lines of intersections properly numbered	______

Directions: Usually the procedures shown in the following examples to construct intersections of surfaces using edge views. Be sure to reference the examples as you complete your work.

Example:

1. Identify and label all edge views (EV) and label all points.

   Note: If edge views are not given, use auxiliary views to find them.

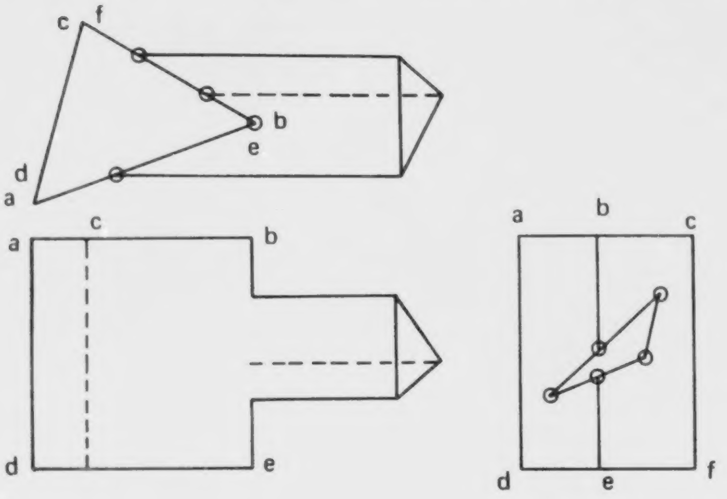


Assignment Sheet 8

2. Observe edge views and circle points at the end of lines that intersect the edge views; these are called piercing points.

   a. Since all three piercing points are not on the same plane, line "be" should also be circled to make the line of intersection continuous.

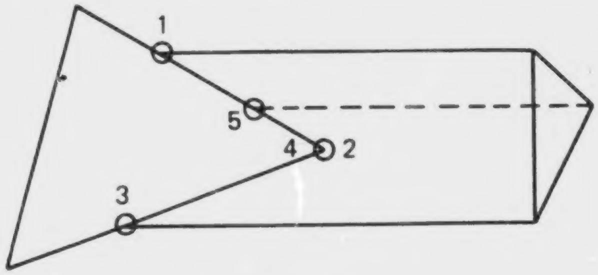
   b. Circle piercing points where "be" intersects the edges in the side view.



3. Follow the line of intersection between the two objects numbering them as you go.

   a. 1 and 2 are on the same top surface.

   Note: Point 5 is hidden and is on the bottom surface.



   b. Line 2-3 is on the top surface.

   c. Line 3-4 is on the bottom surface.

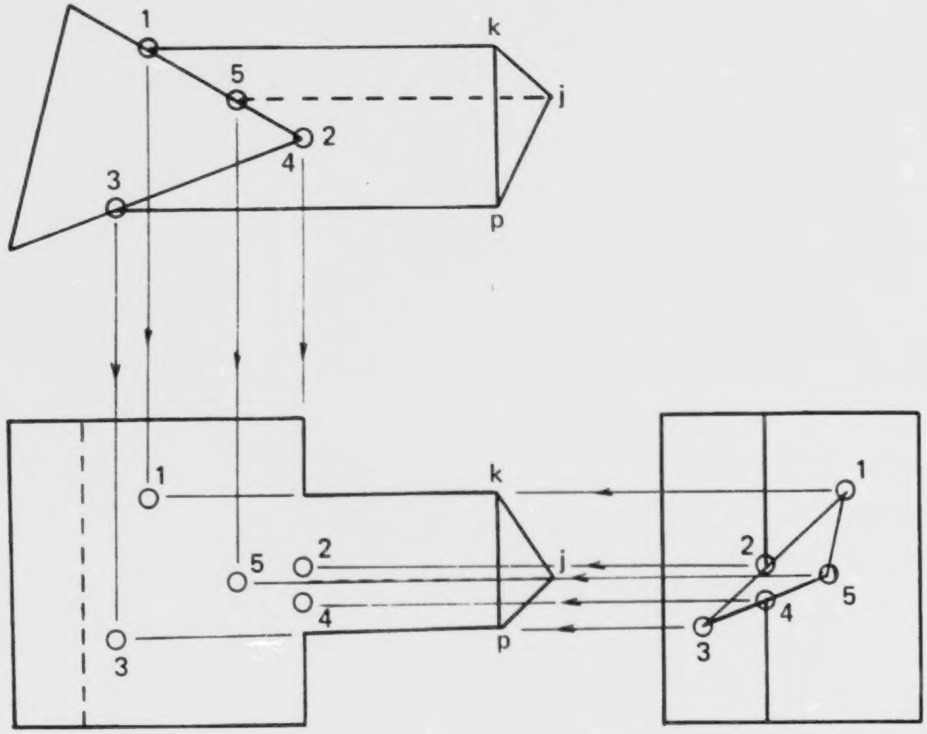
   d. Line 4-5 is on the bottom surface.

Assignment Sheet 8

e. Line 5-1 is on the bottom surface.

f. The line of intersection is continuous ending with the same start point; your ability to visualize is very important in this process.

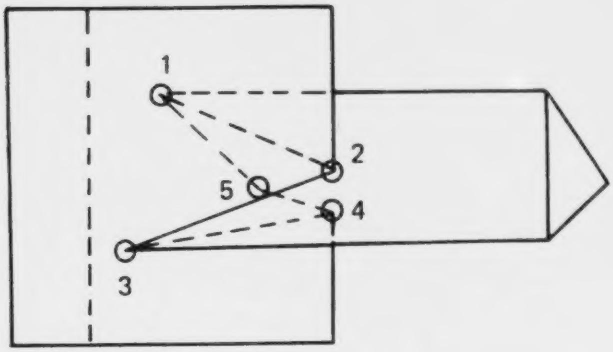
4. Project piercing points to front view intersecting corresponding lines; circle intersections.

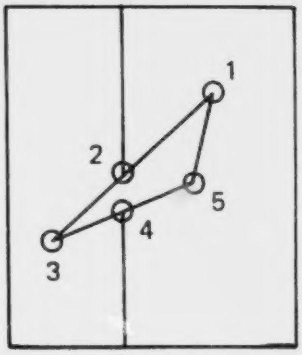


Note: Points 2 and 4 must be projected from the side view. Another method for finding the piercing point of a line and a plane is the two-view method which will be covered in Assignment Sheet 9.

Assignment Sheet 8

5. Connect piercing points to form line of intersection; use visualizing skills to determine visibility and if lines are near the observer or far from the observer.

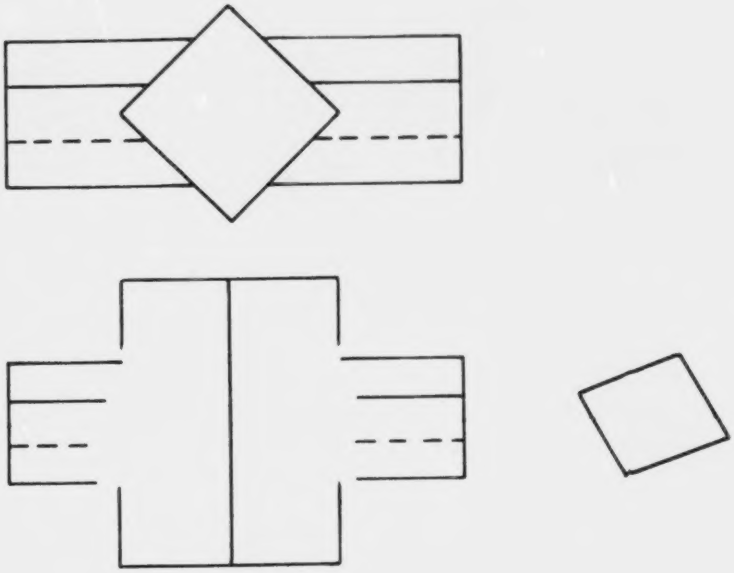




Problems:

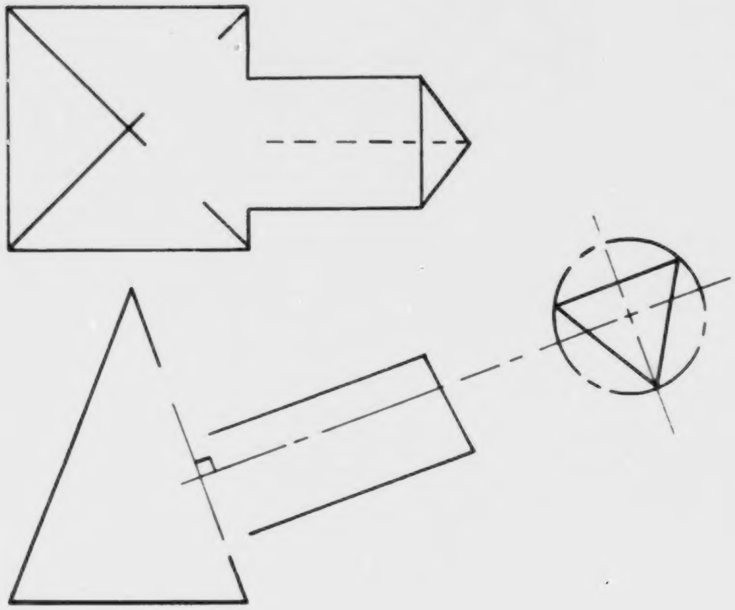
Construct line of intersection between the parts shown. Circle piercing points and number line of intersection on all views.

A.

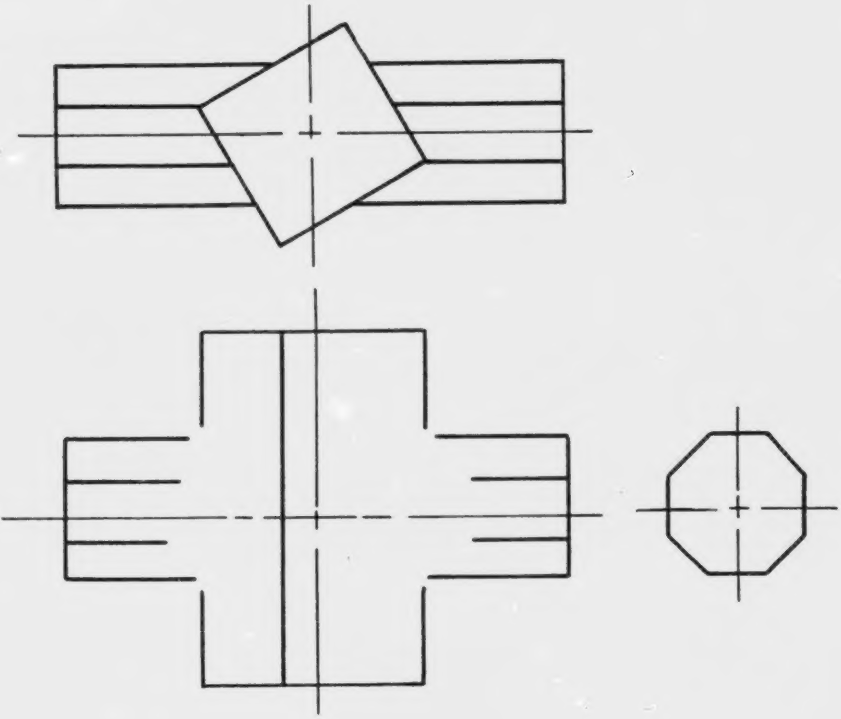


Assignment Sheet 8

B.

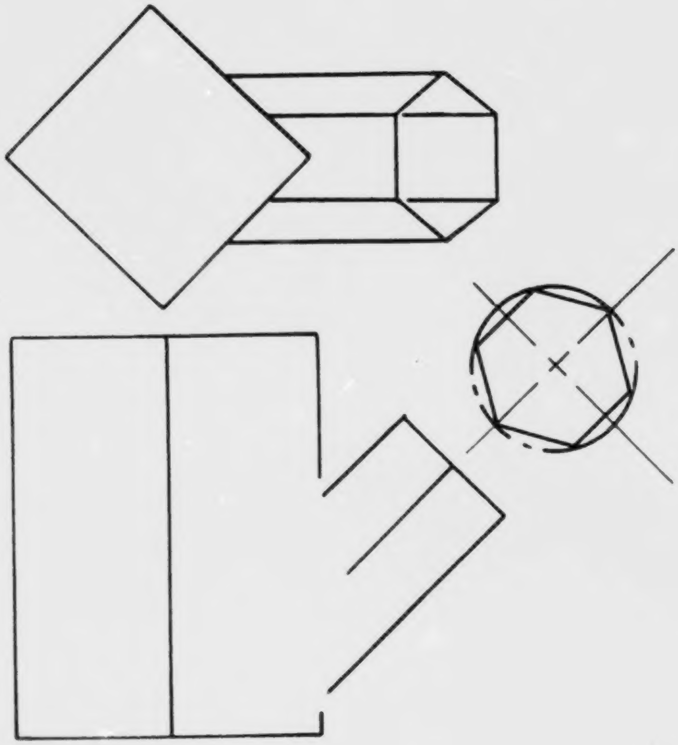


C.



Assignment Sheet 8

D.



Sheet Metal Developments
Unit 9

Assignment Sheet 9—Construct Intersections Of Surfaces Using The Two-View Method

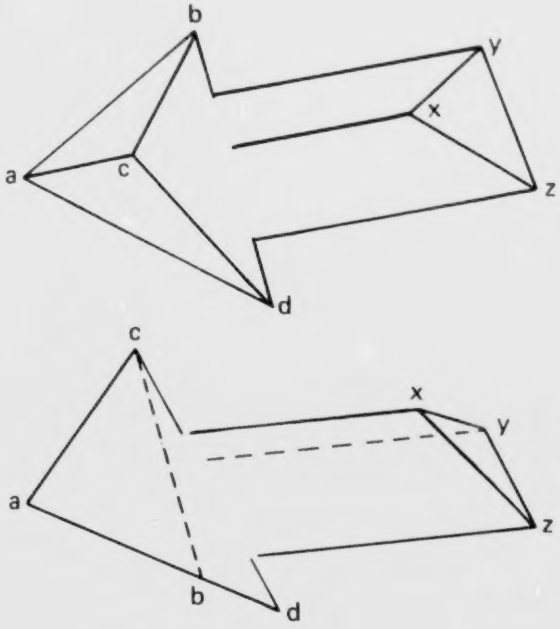
Name ______________________________ Overall Rating __________

Evaluation criteria	Rating
Use of two-view method for lines of intersection constructed	______
Piercing points properly circled	______
Lines of intersections properly numbered	______

Directions: Use the procedures shown in the following examples to construct intersections using the two-view method. Be sure to reference the examples as you complete your work.

Example:

1. Identify and label all edge views, if given, and label all points.

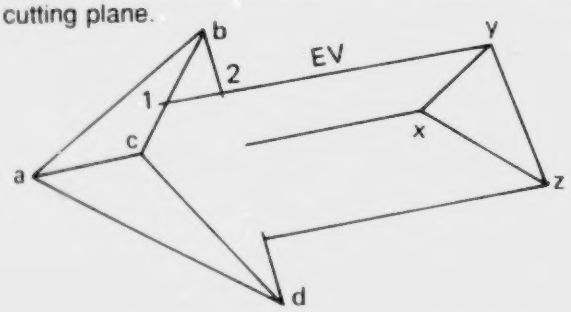


Assignment Sheet 9

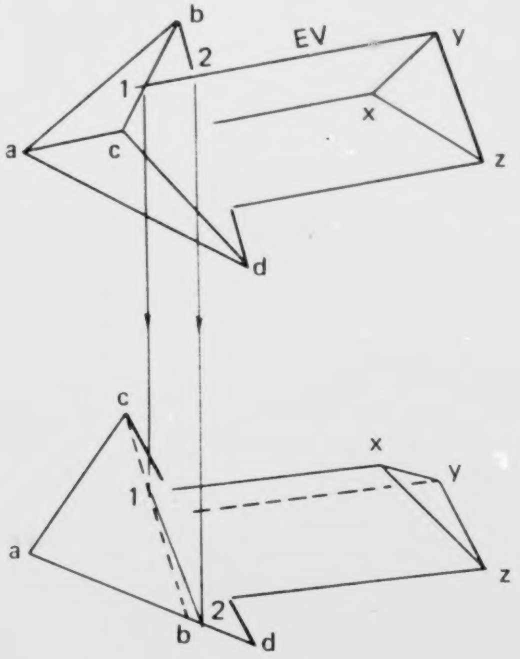
2. Take each line independently and locate its piercing point on the surface.

   a. Extend the line until it crosses two lines cb and bd on the plane you expect it to intersect; label intersections #1 and #2.

      Note: In this method, the line is marked EV to indicate the edge of an imaginary cutting plane.

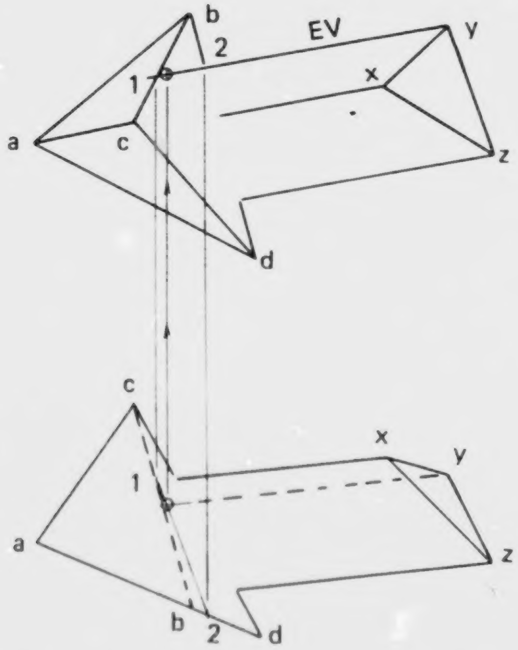


   b. Project points 1 and 2 to adjacent front view to intersect lines cb and bd.

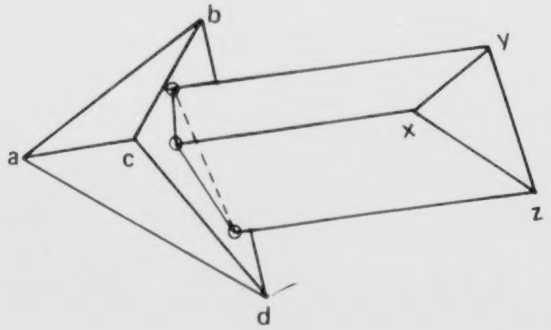


Assignment Sheet 9

c. Draw a line between 1 and 2 where it intersects the line Y-that is a piercing point; mark piercing point, and project back to the one that we marked EV.

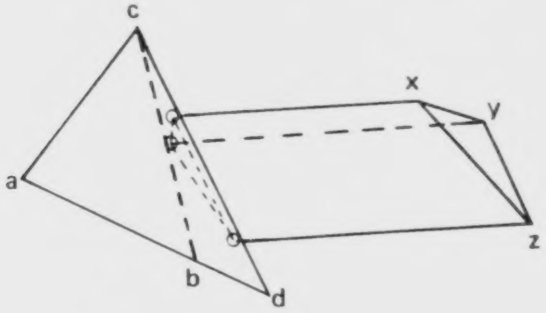

b
2
EV
y
1
x
a
c
z
d
c
x
y
1
a
z
b
2
d

d. Use the same process to locate all piercing points.



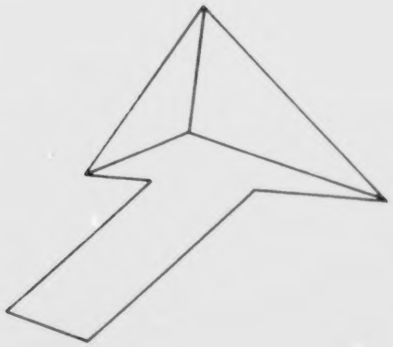
Assignment Sheet 9

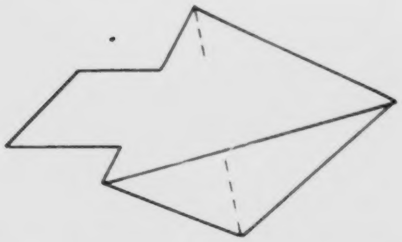
e. Connect piercing points to form line of intersection; use visualizing skills to determine visibility and if lines are near the observer or far from the observer.



Problems: Construct line of intersection between the parts shown. Use two-view method where appropriate. Circle piercing points and number line of intersection on all views.

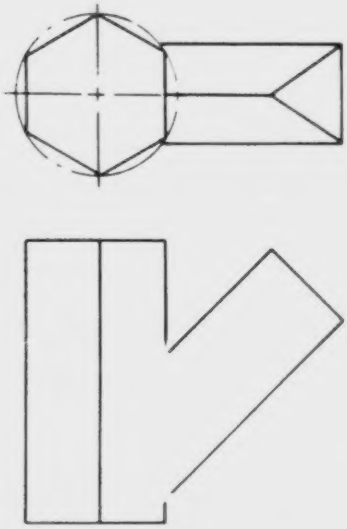
A.



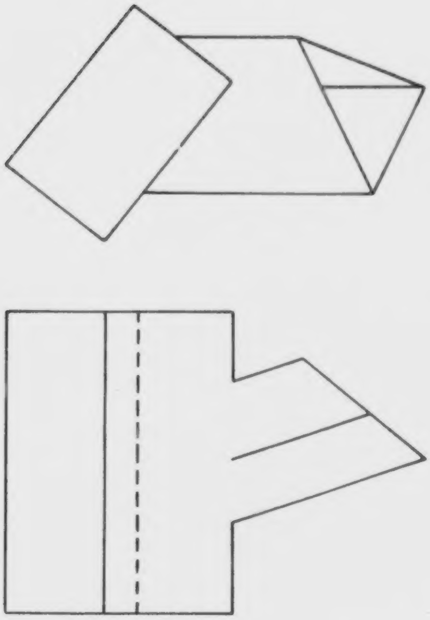


Assignment Sheet 9

B.

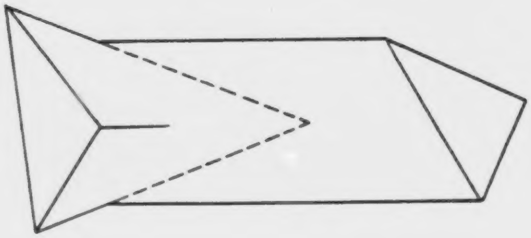


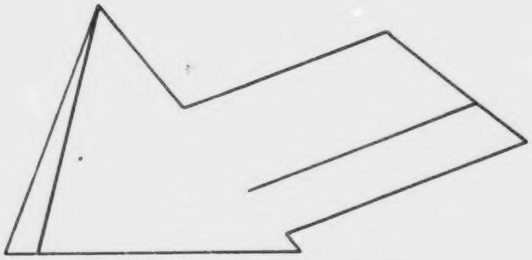
C.



Assignment Sheet 9

D.





Sheet Metal Developments
Unit 9

Assignment Sheet 10—Construct Radial Line Developments

Name ______________________________ Overall Rating __________

Evaluation criteria	Rating
Two-view drawing and development	_____
Preparation and development of three-dimensional part	_____
Wire frame alternate	_____

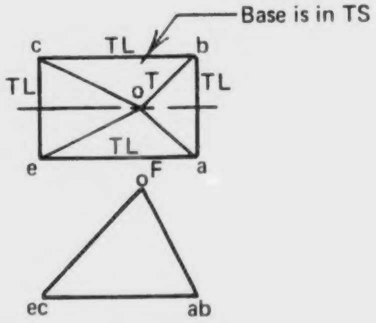
Introduction: The objective of constructing sheet metal developments is to draw a true size flat pattern of the surface to be folded to the desired form. Edges are joined by seams, rivets, welding, soldering, and other means. Edge lengths should be kept to a minimum for economy and ease of handling.

Directions: Construct radial line developments of pyramids, truncated pyramids, right circular cones, and oblique cones. An example is included for each of these. If a CAD system is available, select one of the assigned drawings and draw it with the CAD system.

> **CAD Alert:** Use a CAD system to construct your radial line development in 2D. If you have an unfold program, construct a 3D wireframe and use the unfold program to complete development.

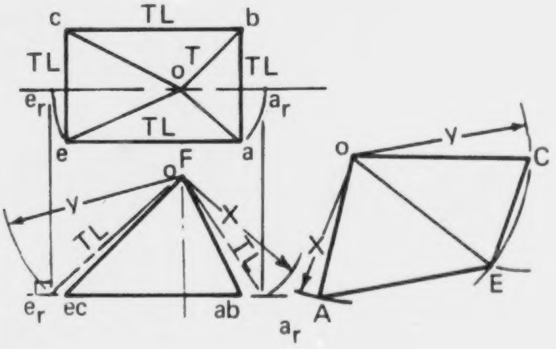
Example A: Pyramids

1. Label all points, true length lines, and true size surfaces.



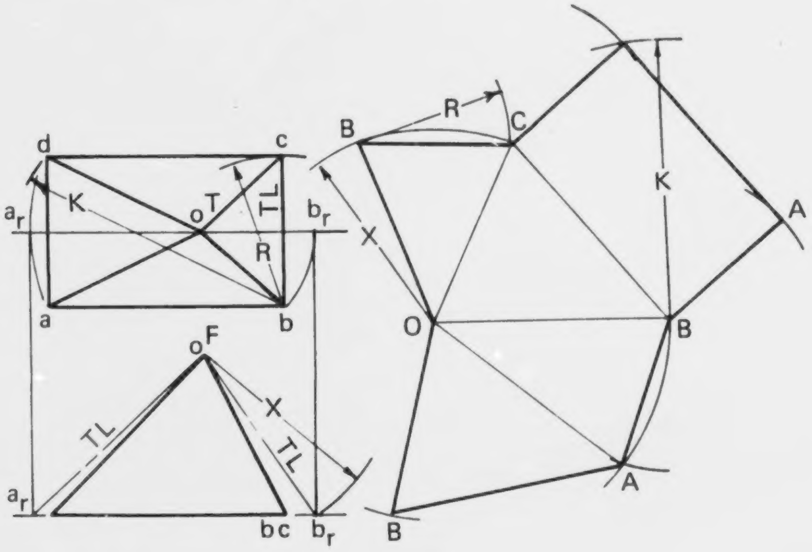
Assignment Sheet 10

2. Find the true lengths of each inclined or oblique lines by rotation using the vertex as the axis.


c
TL
b
TL
o
T
TL
e_r
a_r
TL
e
a
o
F
y
X
TL
TL
y
X
o
C
E
A
a_r
e_r
ec
ab

3. Decide where the seams will be located.

4. Lay out the surfaces in true size inside out.


d
c
a_r
K
o
T
TL
b_r
R
a
b
o
F
X
TL
TL
a_r
bc
b_r
B
R
C
K
A
X
O
B
A
B

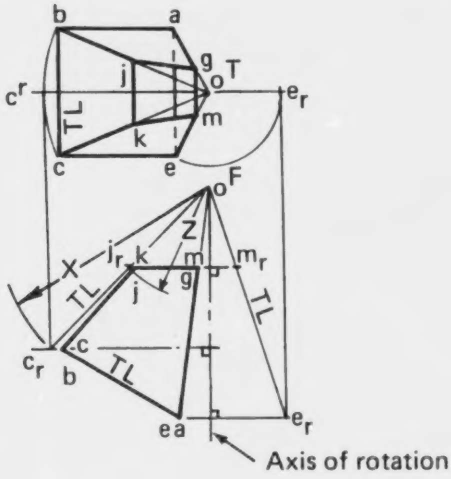
5. Complete the development making bend lines thin lines.

Note: Notice the use of the diagonal distance "K" to transfer the rectangle.

Assignment Sheet 10

Example B: Truncated pyramids

1. Label all points, true length lines, and true size surfaces.

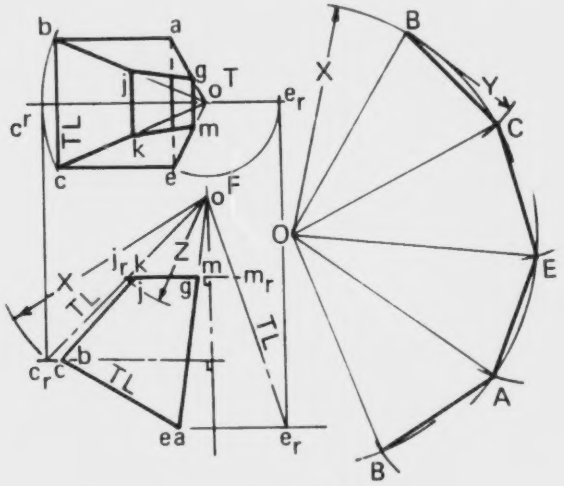

b
a
g
o^T
j
c^r
e_r
TL
m
k
c
e
o^F
Z
X
j_r
k
m
m_r
TL
j
g
TL
TL
c
c_r
b
e a
e_r
Axis of rotation

2. Find the true lengths of each inclined or oblique line by rotation using the vertex as center.

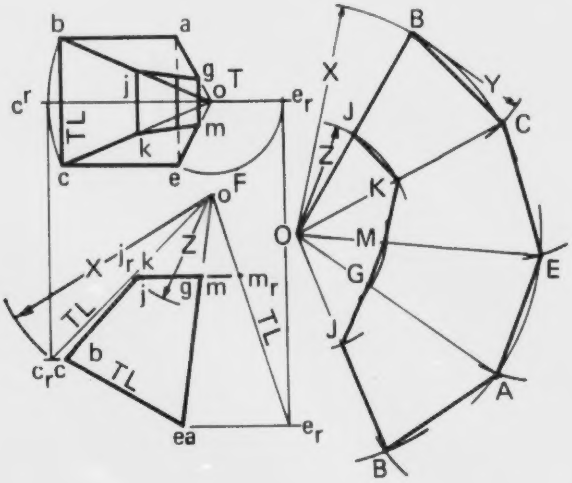
3. Since the object does not go to the vertex, project the intermediate distances perpendicular to the axis of rotation to obtain correct true lengths.

Assignment Sheet 10

4. In more complicated drawings a true length diagram is use to keep the drawing from becoming confusing.


b
a
g
o T
j
e r
c r
TL
m
k
c
e
o F
O
X
j r
k
Z
m
m r
j
g
TL
X
c r c
b
TL
TL
ea
e r
B
X
Y
C
E
A
B

5. Lay out the largest surfaces in true size inside up.


b
a
g
o T
j
e r
c r
TL
m
k
c
e
o F
O
X
j r
k
Z
m
m r
j
g
TL
X
c r c
b
TL
TL
ea
e r
B
X
Y
J
Z
C
K
M
E
G
J
A
B

Assignment Sheet 10

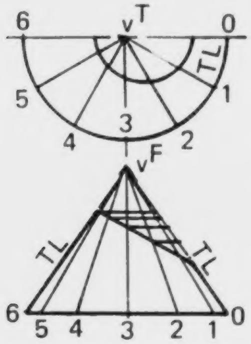
6. Lay out the smaller true lengths on the true length lines on the development.

7. Complete the development making bend lines thin lines.

Example C: Right circular cones

1. Label all points, true length lines, and true size surfaces.

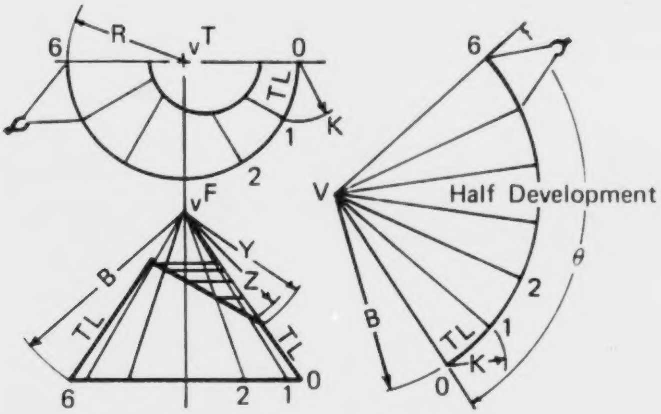
   Note: This example does not have any true size surfaces.


6
vT
0
TL
5
1
3
4
2
vF
TL
TL
6
5 4 3 2 1
0

Note: By observation, the base of the cylinder is in true size in the top view.

2. Divide circular base into equal parts (normally every 15° or 30°) and draw the cone elements t the vertex; number each point.

3. Project elements to the front view and draw to the vertex.


6
R
vT
0
TL
K
1
2
vF
Y
B
Z
TL
TL
6
2 1
0
6
V
Half Development
θ
2
B
TL
1
K
0

Assignment Sheet 10

4. Using the true length of the side of the cone as the radius, construct a semi-circle.

5. Use the following formula to compute the number of degrees of the semi-circle for a half development.

   Note: In this example, R = 10; B = 20.

   $\theta = 1/2\ (\frac{R}{B} \times 360^\circ)$

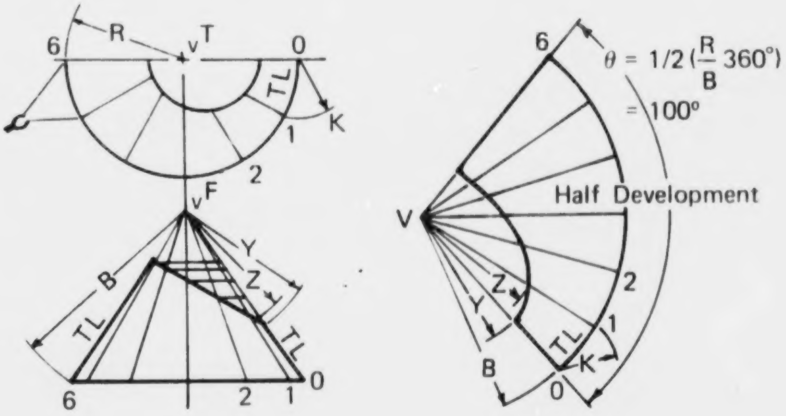
   $\theta = 1/2\ (\frac{10}{20} \times 360^\circ)$

   $\theta = 90^\circ$

   Note: When the formula is used, the elements must be stepped off with dividers to divide the arc equally.

6. An alternate method, not as accurate, can be used.

   a. Step the chord distance from 0 to 1, etc. around the semi-circle.



6
R
T
0
TL
K
1
2
F
Y
B
Z
TL
TL
6
2
1
0
6
$\theta = 1/2\ (\frac{R}{B}\ 360^\circ)$
= 100°
Half Development
V
2
Z
Y
1
TL
K
B
0

   b. Construct the larger circle with a bow compass.

   c. Lay out the smaller true lengths on the developed true length lines.

   d. Connect all points with an irregular curve.

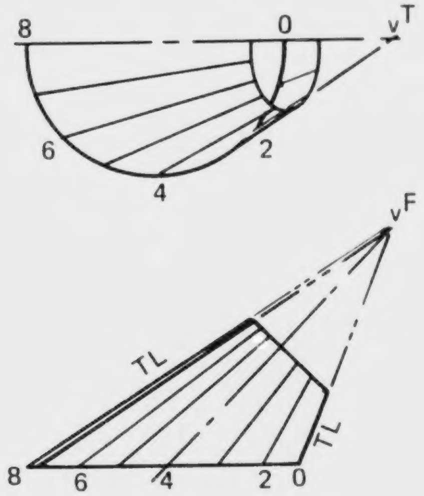
   e. Complete the development by darkening all lines.

Assignment Sheet 10

Example D: Oblique cones

1. Label all points, true length lines, and true size surfaces.

   Note: This example does not have any true size surfaces.



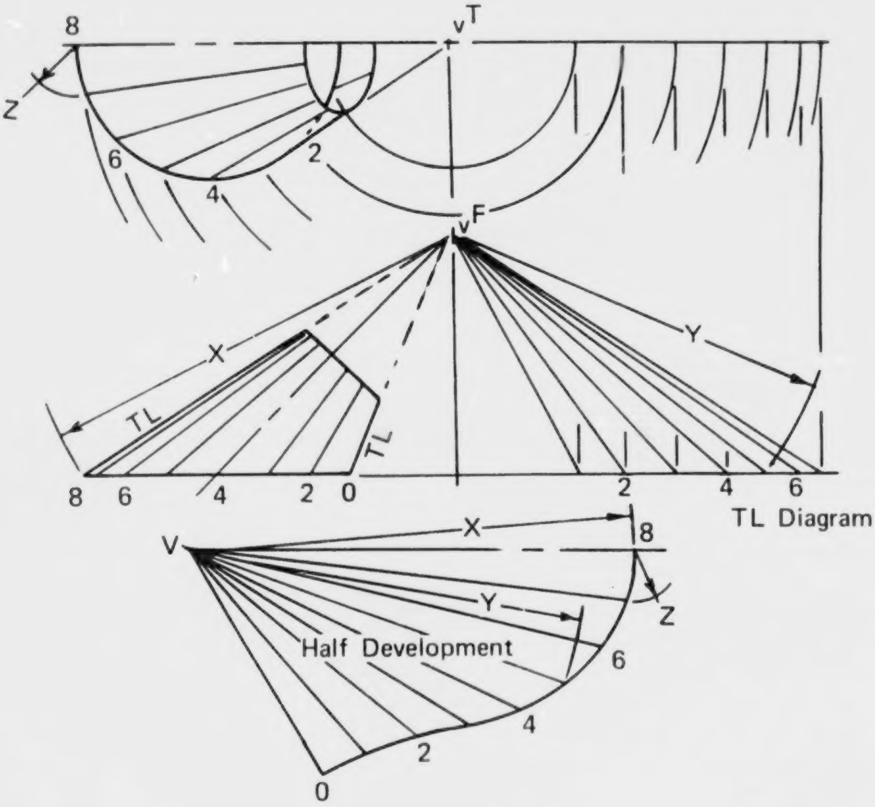
2. Divide circular base into equal parts and draw the cone elements to the vertex; number each point.

3. Construct a true length diagram by rotating points on the right side of the drawing.

   Note: This helps to prevent confusion.

Assignment Sheet 10

4. Project all elements intersection of the inclined surface to the TL diagram; this will give the correct length for the cut.

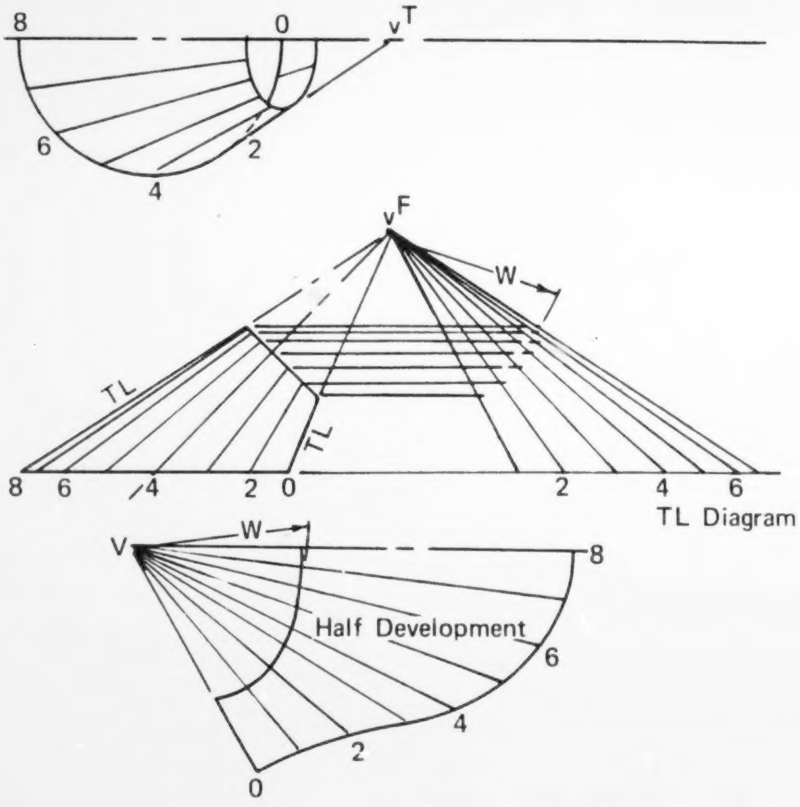

8
v T
Z
6
4
2
v F
X
TL
TL
Y
8
6
4
2
0
2
4
6
TL Diagram
V
X
8
Z
Y
Half Development
6
4
2
0

Half Development

5. Lay out one true length element at a time and one circular radius between elements at a time.

Assignment Sheet 10

6. Connect all points using an irregular curve.


8
0
V T
6
2
4
V F
W
TL
TL
8
6
4
2
0
2
4
6
TL Diagram
V
W
8
Half Development
6
4
2
0

Half Development

7. Lay out the smaller true lengths on the developed true length lines.

8. Connect all points with an irregular curve.

9. Complete the development by darkening all lines.

Problems:

1. Construct each problem on a "B" size sheet of vellum or other media selected by instructor. Draw both the two view drawing and the development. Add dimensions as instructed.

2. Make a blueline print of the drawing and cut the pattern out with scissors.

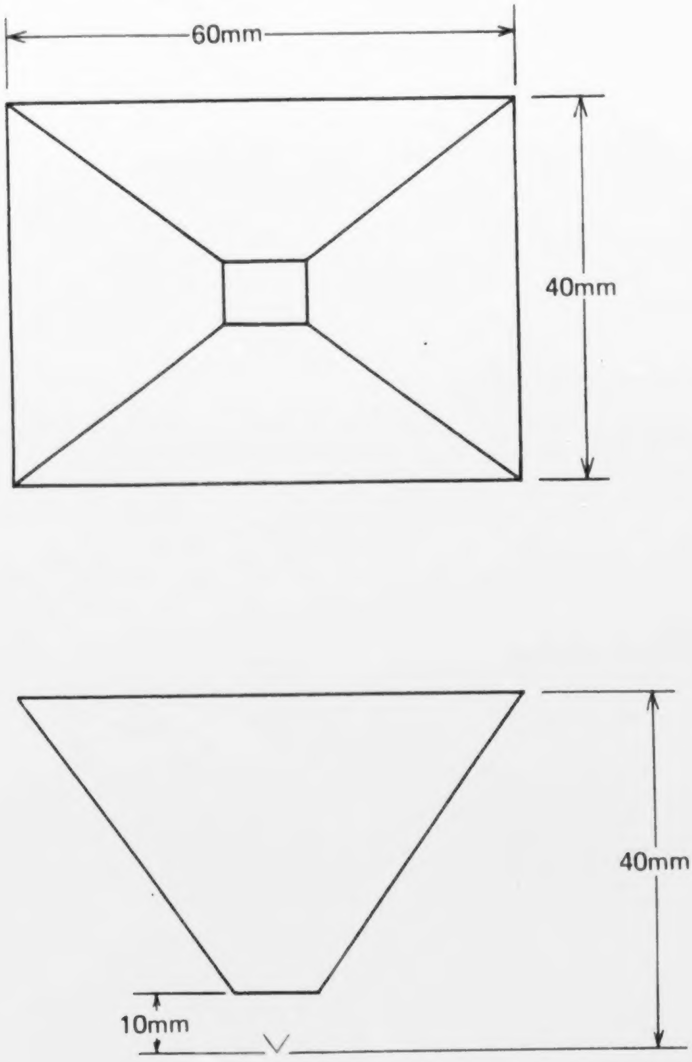
Assignment Sheet 10

3. Tape or glue development together to form three dimensional part.

CAD Alert: Use a CAD program to make wireframes of each problem, and use an "unfold sheet metal" program to produce development.

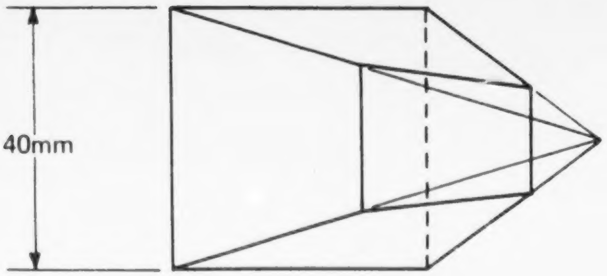
4. Hand in both the original and the object to your instructor.

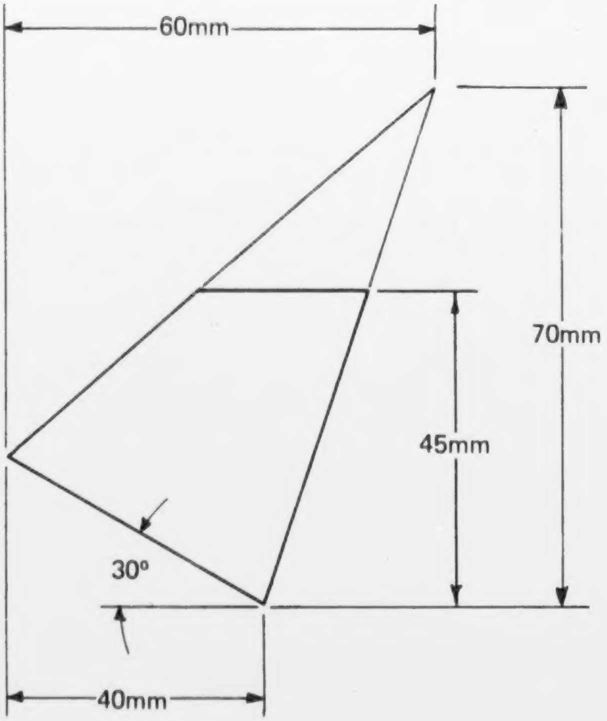
A.



Assignment Sheet 10

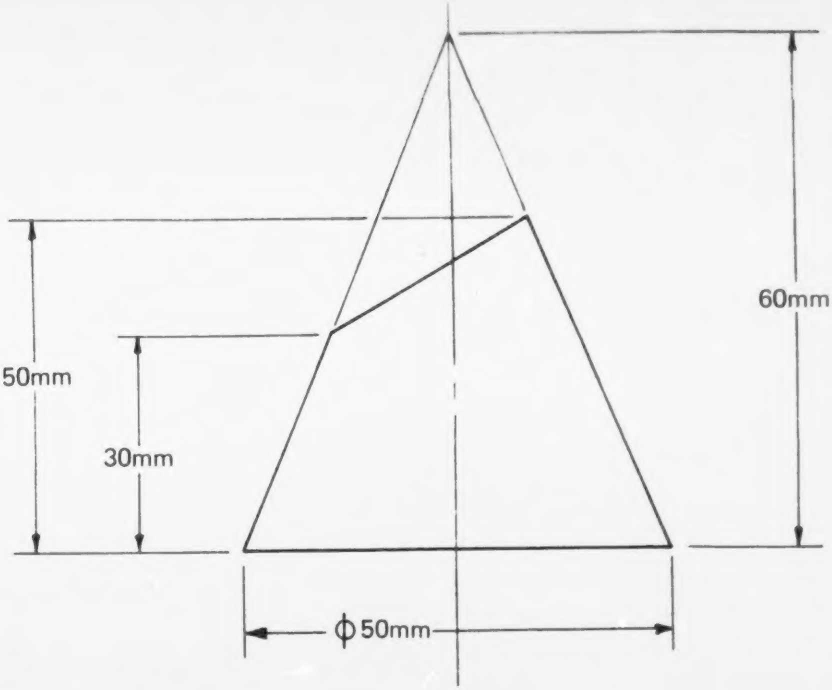
B.




60mm
70mm
45mm
30°
40mm

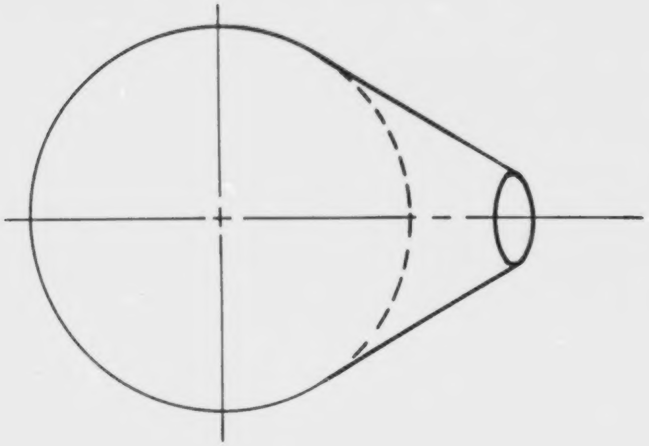
Assignment Sheet 10

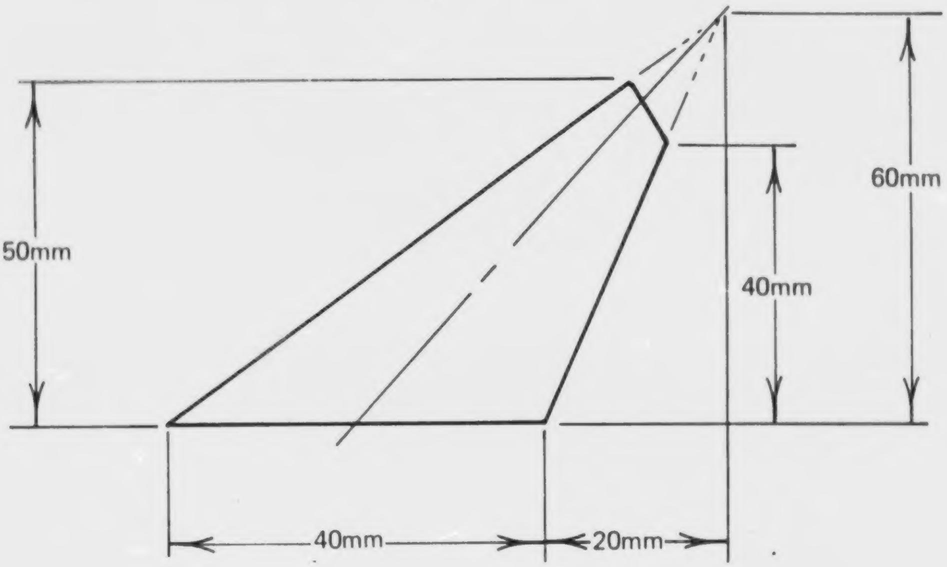
C.


60mm
50mm
30mm
ϕ50mm

Assignment Sheet 10

D.




50mm
60mm
40mm
40mm
20mm

Sheet Metal Developments
Unit 9

Assignment Sheet 11—Construct Parallel Line Developments

Name ______________________ Overall Rating __________

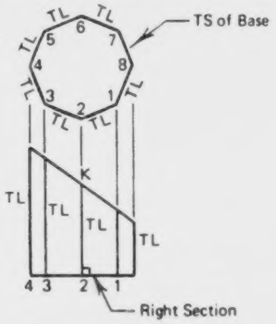
Evaluation criteria	**Rating**
Two view drawing and construction line development	______
Preparation and development of three-dimensional part	______
Wire frame alternate on CAD system	______

Directions: Construct parallel line developments of right prisms, oblique prisms, right circular cylinders, and oblique cylinders on "B" size media. Examples for each of these are included to be used as guidelines for solving the problems. If a CAD system is available, draw one of the assigned drawings in CAD.

> **CAD Alert:** Use a CAD system to construct your parallel line development in 2D. If you have an unfold program, construct a 3D wireframe and use the unfold program to complete development.

Example A: Right prisms

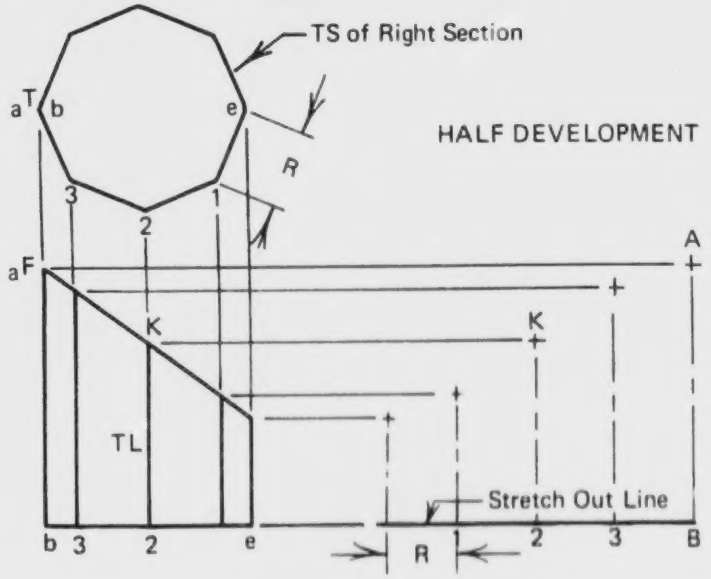
1. Label all points, true length lines, and true size surfaces.



Note: All lines are in true length except the inclined lines. Since the base is perpendicular to the octagon shaft, the corners formed on the planes are 90°. The top view is a right section of the base. When you have a right section, the solution to the problem is to transfer distances from the right section on a stretch out line.

Assignment Sheet 11

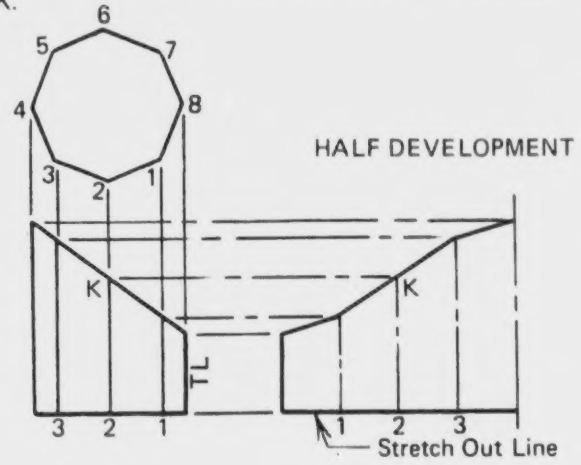
2. Project from the right section to the right hand area all true length vertical lines.


TS of Right Section
a_T
b
e
R
3
2
1
HALF DEVELOPMENT
A
a_F
K
K
TL
Stretch Out Line
b
3
2
e
R
1
2
3
B

3. On the EV of the right section, mark off the true lengths of the base; this line is called a stretch out line.

   Note: If a right section is not given, construct a right section perpendicular to the true length lines.

4. Draw the lines from the points on the base until they connect to the common points such as 2 connects to K.


6
5
7
4
8
3
2
1
HALF DEVELOPMENT
K
K
TL
3
2
1
1
2
3
Stretch Out Line

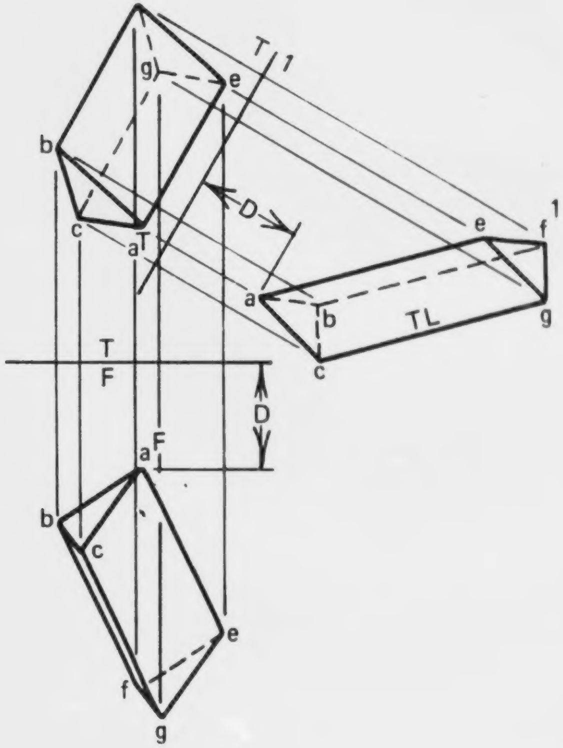
5. Complete the development making bend lines thin lines.

Assignment Sheet 11

Example B: Oblique prisms

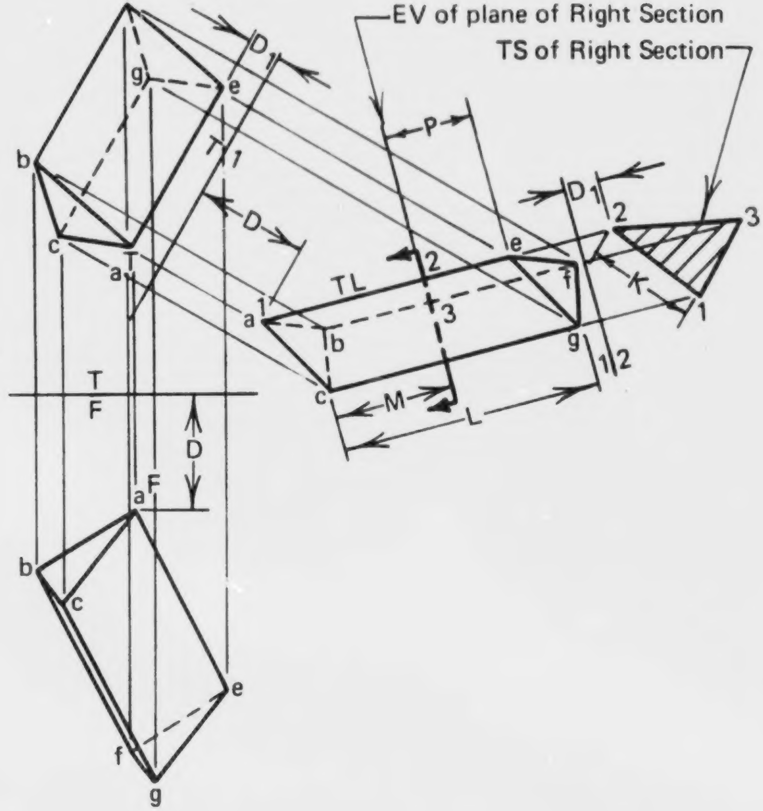
1. Label all points, true length lines, and true size surfaces.

   Note: This example has no true length lines or true size surfaces.



2. To develop an oblique prism that has no true length sides given, construct an auxiliary view to find the true lengths of the parallel sides.

Assignment Sheet 11

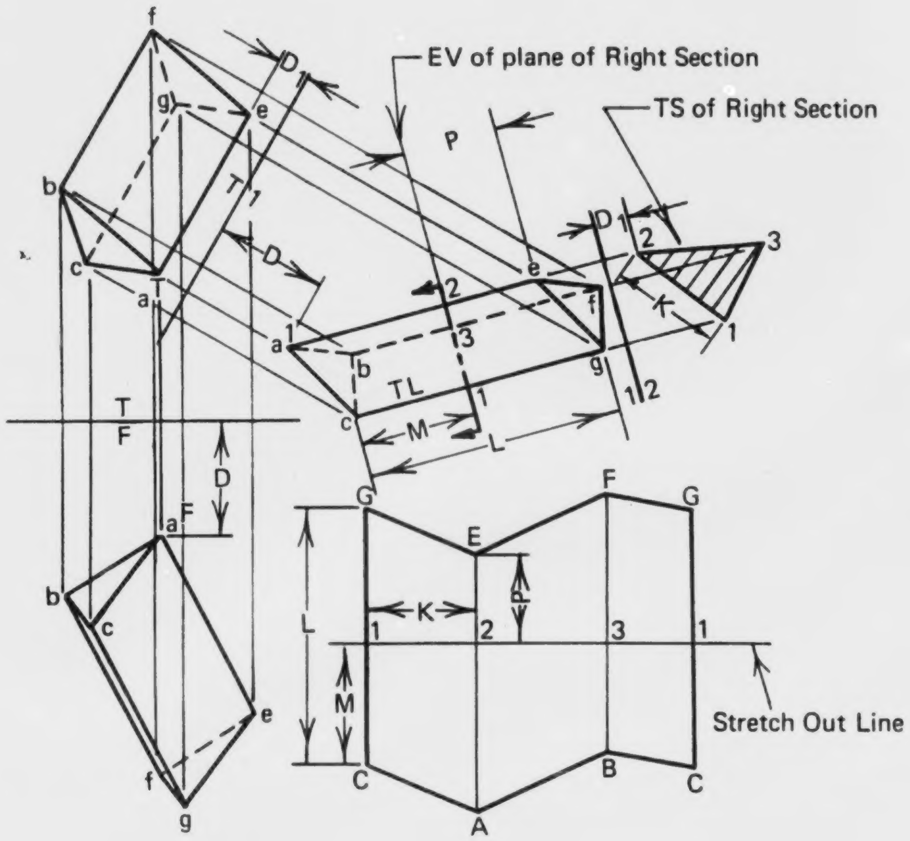

EV of plane of Right Section
TS of Right Section
f
g
e
b
c
a
T
D
D1
T
1
P
TL
1
2
3
a
b
c
e
f
g
M
L
D1
2
3
K
1
1
2
T
F
D
a
F
b
c
e
f
g

3. Construct a true right section at a convenient location perpendicular to the TL of the parallel lines.

   Note: This view is an edge view of the section.

4. Construct the true size of the right section by constructing the line of sight parallel to the true length lines.

Assignment Sheet 11


f
EV of plane of Right Section
TS of Right Section
D
D_1
g
e
P
b
T_1
D
D_1
1
2
3
c
a
T
e
2
f
K
1
a
1
b
3
TL
g
1
1
2
T
F
c
M
L
D
G
F
G
a^F
E
b
c
L
K
1
2
3
1
M
e
Stretch Out Line
f
C
B
C
g
A

5. In a convenient location draw a horizontal stretch out line.

6. Transfer the true lengths of the sides from the TS right section view.

7. Construct vertical lines through the points.

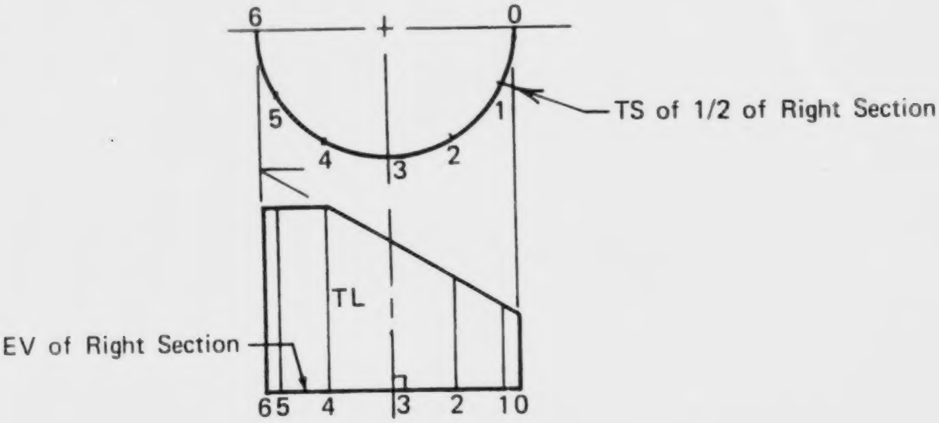
8. Transfer true lengths of sides from the EV of the right section to the vertical lines.

9. Complete the development making bend lines thin lines.

Assignment Sheet 11

Example C: Right circular cylinders

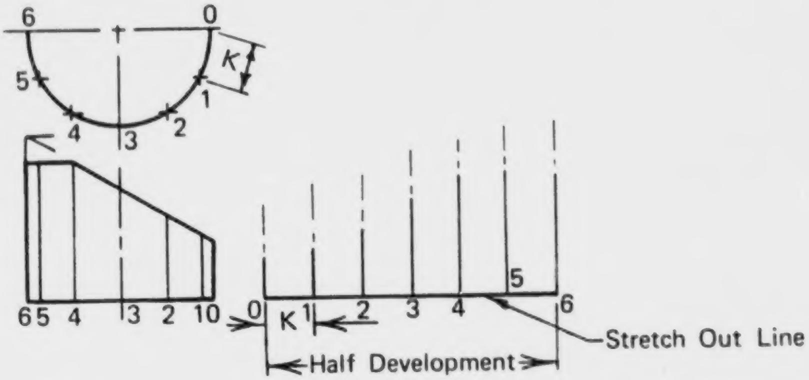
1. Label all points, true length lines, and true size surfaces.


6
0
5
1
4
3
2
TS of 1/2 of Right Section
TL
EV of Right Section
6 5 4 3 2 1 0

2. By observation, the base of the cylinder is in true size in the top view.

3. Divide circular base into equal parts (normally every 15° or 30°).

4. Project points (actually end view of elements) to front view and draw the elements parallel to the center line.


6
0
K
5
1
4
3
2
6 5 4 3 2 1 0
0 K 1 2 3 4 5 6
Stretch Out Line
Half Development

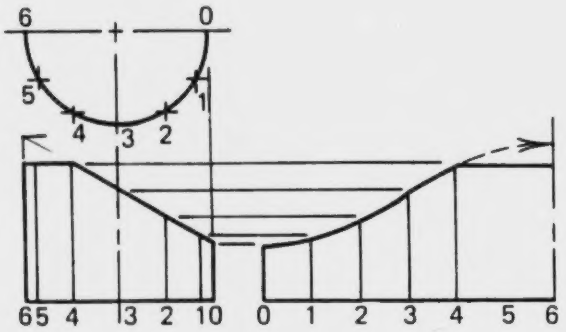
5. Project horizontal stretch out line from EV of right section.

6. Transfer distances from top view from point 0 - 1 to stretch out line.

Note: The distance laid out is 1/2 circumference.

Assignment Sheet 11

7. Project vertical lines from each point on stretch out line.

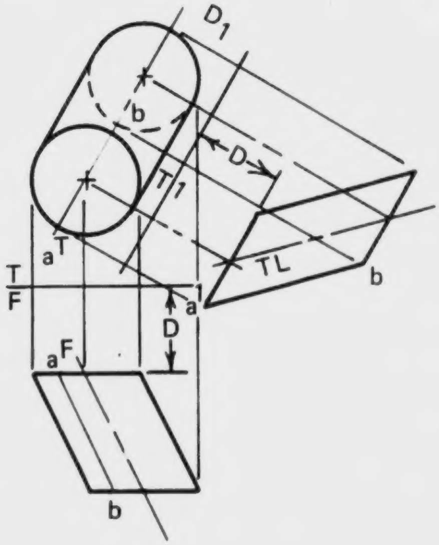


8. Project points from inclined top edge of elements in front view to corresponding elements in development area.

9. Complete the developments by connecting points with an irregular curve.

Example D: Oblique cylinders

1. Label all points, true length lines, and true size surfaces.



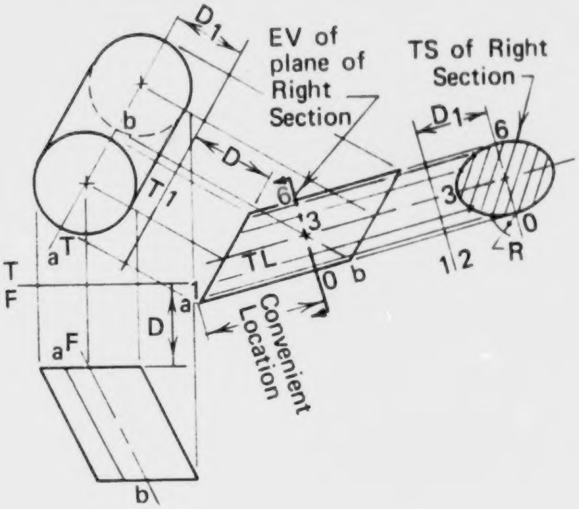
2. To develop an oblique prism that has not true length center line given, construct an auxiliary view to find the true length of the center line.

Assignment Sheet 11

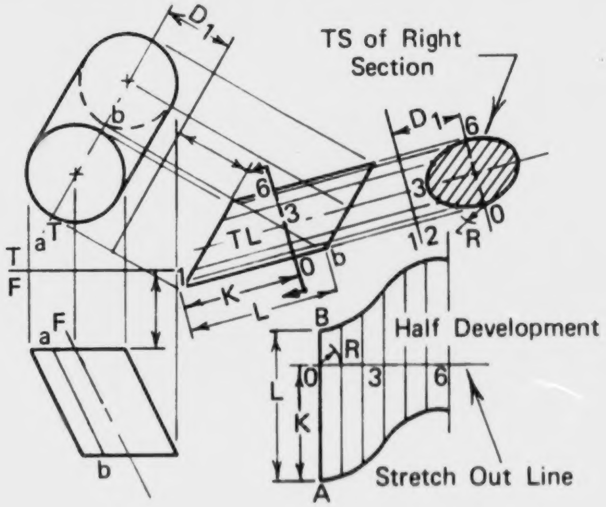
3. Construct a true right section at a convenient location perpendicular to the TL of the center line.

   Note: This view is an edge view of the section.

4. Construct the true size of the right section by constructing the line of sight parallel to the TL of the center line.


D1
EV of plane of Right Section
TS of Right Section
D1
6
b
D
6
T1
3
3
0
R
T
a
TL
0
b
1
2
F
1
a
D
Convenient Location
a
F
b

5. Divide the ellipse right section into equal parts and project back to view with TL center line; these lines are elements of the cylinder and are in TL.


D1
TS of Right Section
D1
6
b
6
3
3
0
a
T
TL
0
b
1
2
R
T
F
1
K
L
B
Half Development
a
F
R
L
0
3
6
K
b
A
Stretch Out Line

Assignment Sheet 11

6. In a convenient location, draw a horizontal stretch out line.
7. Transfer the distances between the point view of the elements in the TS right section view to the stretch out line.
8. Project vertical lines from each point on the stretch out line.
9. Transfer TL of elements from the EV of the right section to the vertical lines.
10. Complete the view using an irregular curve.

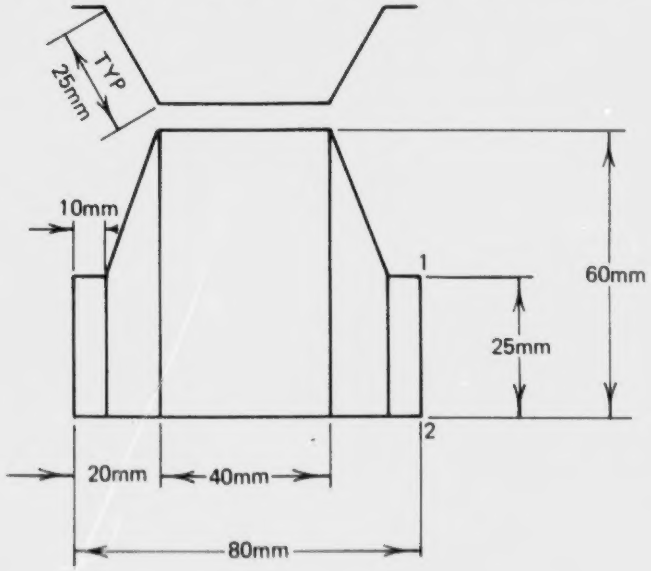
Problems:

1. Construct a development for each problem on a "B" size sheet of vellum or other media selected by instructor. Draw both the two view drawing with all construction lines and the development. Add dimensions as required by instructor.
2. Make a blueline print of the drawing and cut the pattern out with scissors.
3. Tape or glue development together to form three dimensional part.

> **CAD Alert:** Use a CAD program to make wireframes of each problem, and use an "unfold sheet metal" program to produce development.

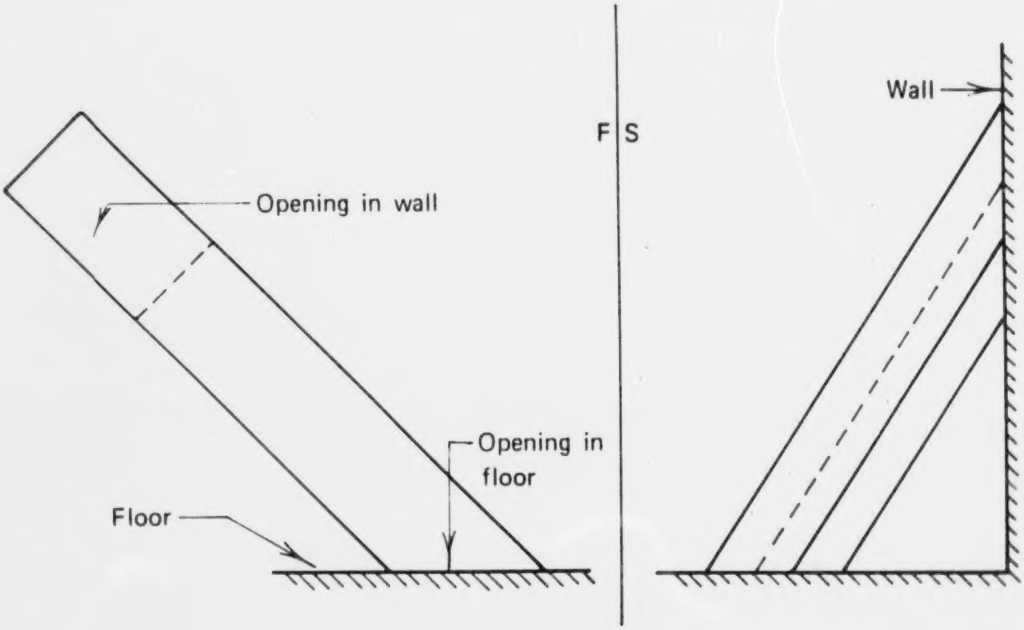
4. Hand in both the original and the object to your instructor.

A.

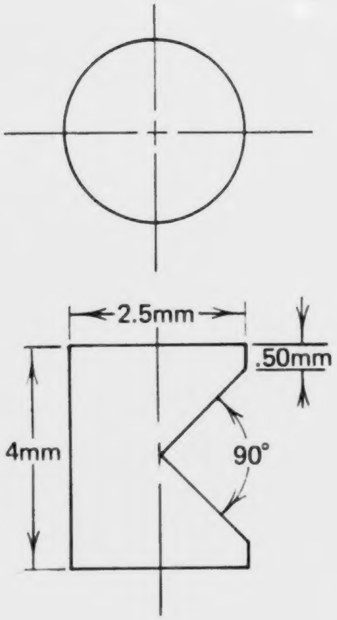


Assignment Sheet 11

B. Transfer dimensions to "B" size media. Part is inclined at an angle of 25° to wall.

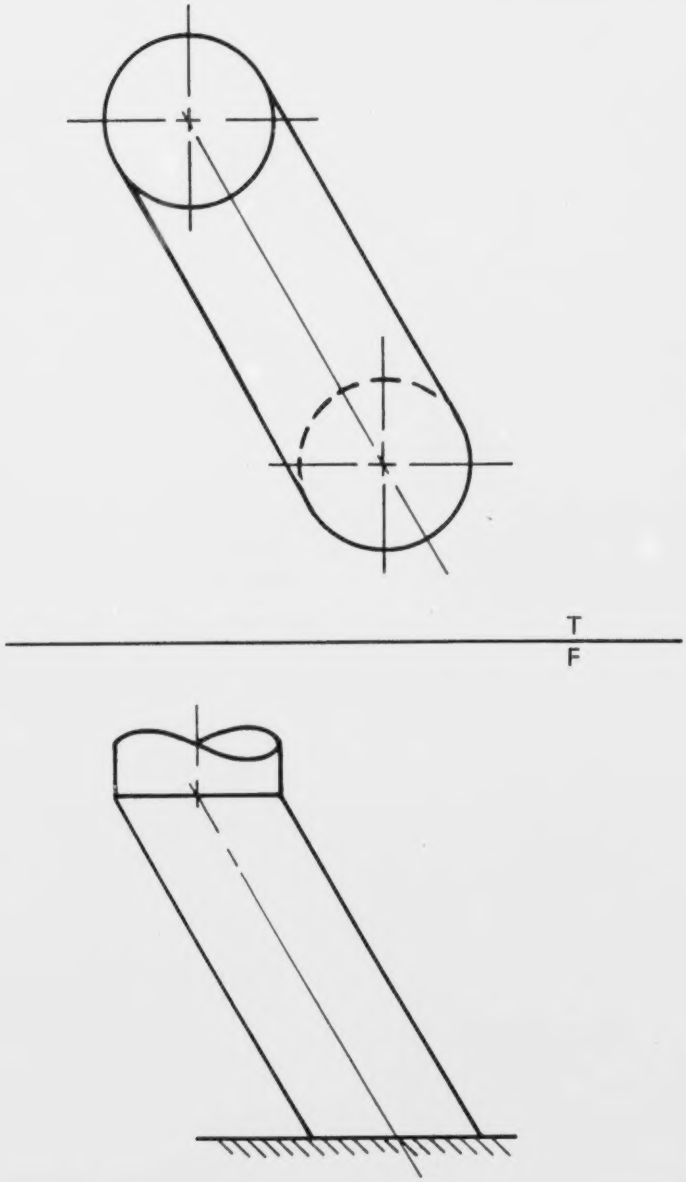

Opening in wall
F
S
Wall
Opening in floor
Floor

C.


2.5mm
.50mm
4mm
90°

Assignment Sheet 11

D.



Sheet Metal Developments
Unit 9

Assignment Sheet 12—Construct Special Developments Using Triangulation

Name ______________________________ Overall Rating __________

Evaluation criteria	Rating
Two-view drawing and construction line development	______
Preparation and development of three-dimensional part	______
Wire frame alternate on CAD system	______

Introduction: Many surfaces cannot be developed by the radial line or parallel line methods. some of these other surfaces can be developed or approximately developed using triangulation. As the name triangulation implies, this method divides surfaces into triangles which can be easily constructed.

Example: Is this four-sided figure ABCD a flat plane? It looks to be, but when we examine the diagonal lines, we find they do not intersect!

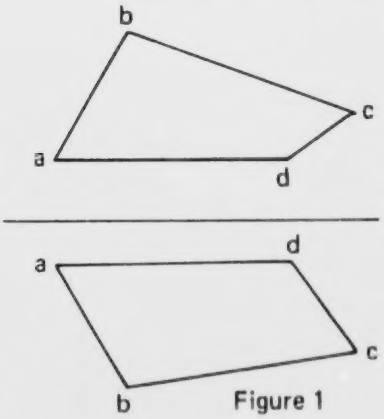


Figure 1

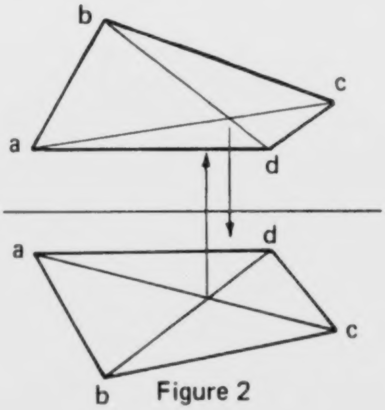
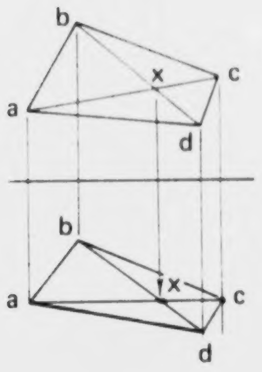


Figure 2

The plane constructed in Figure 1 is not a true flat plane but is, in fact, a warped plane.

To construct a four or more sided plane, we must first divide the surface into triangles, then project the triangles to the adjacent view including the intersection of the diagonals. Line ax is extended to locate point C. The resulting four-sided figure is a flat plane.

Assignment Sheet 12

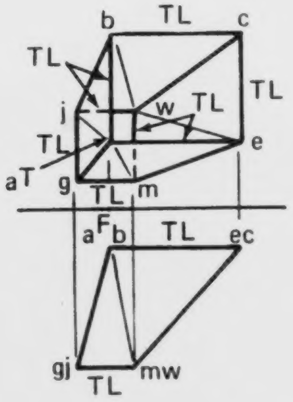


This concept is important when constructing drawings. The optical illusion of a flat plane with four or more sides is easy to draw. Always construct oblique planes with three or more sides using this triangulation method.

Directions: Construct plane surfaces and transition pieces using triangulation on "B" size media. Examples are included to be used as guidelines for solving the problems. If a CAD system is available, draw one of the assigned drawings in CAD.

Example A: Plane surfaces by triangulation

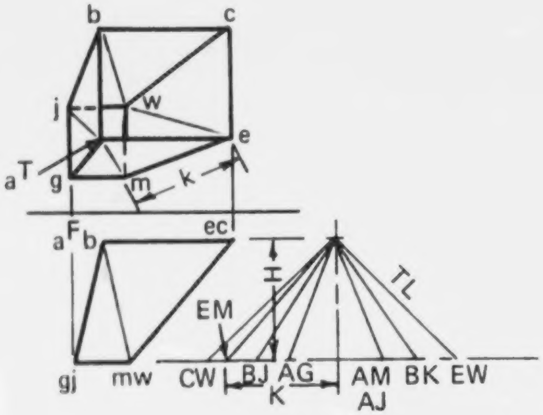
1. Label all points, true length lines, and true size surfaces.



Note: This plane surface hopper is not part of a pyramid and cannot be developed using radial line or parallel line methods.

Assignment Sheet 12

2. Divide each surface into triangles.


b
c
j
w
e
a^T
g
m
k
a^F b
ec
H
TL
EM
gj
mw
CW
BJ
AG
K
AM
AJ
BK
EW

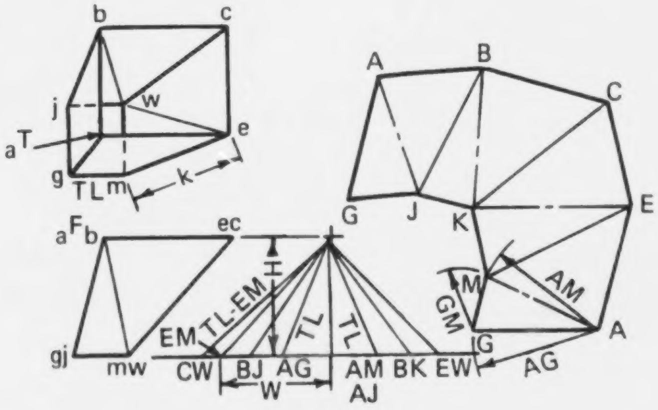
TL Diagram

3. Set up a true length diagram next to the front view to prevent confusion in the front view.

4. Project the height (H) directly to the true length diagram; this is the same as saying, project the edge view of the path of rotation.

5. Transfer directly to the true length diagram the distance (W) that is normally rotated until it is parallel to the folding line.

6. Label all lines correctly on the TL diagram for future use.


b
c
j
w
e
a^T
g
TL m
k
a^F b
ec
H
gj
mw
EM
TL-EM
TL
TL
CW
BJ
AG
W
AM
AJ
BK
EW
A
B
C
G
J
K
E
M
AM
GM
G
A
AG

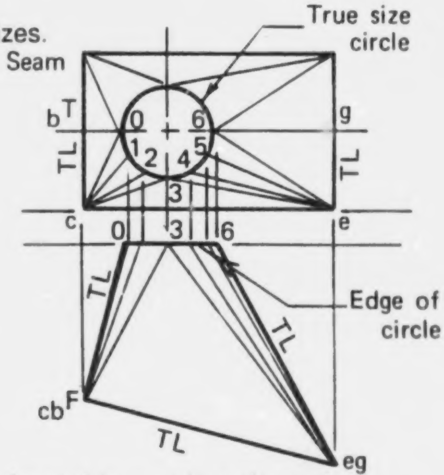
TL Diagram

Assignment Sheet 12

7. Select an open area on the drawing to start the development; allow lots of space.
8. Take true length dimensions of each triangle from those given and those of the TL diagram.
9. Construct the triangles forming the sides of the surfaces; always start with the shortest side.
10. Complete the development adding bend lines.

Example B: Transition piece by triangulation

1. Label all points, true length lines, and true sizes.

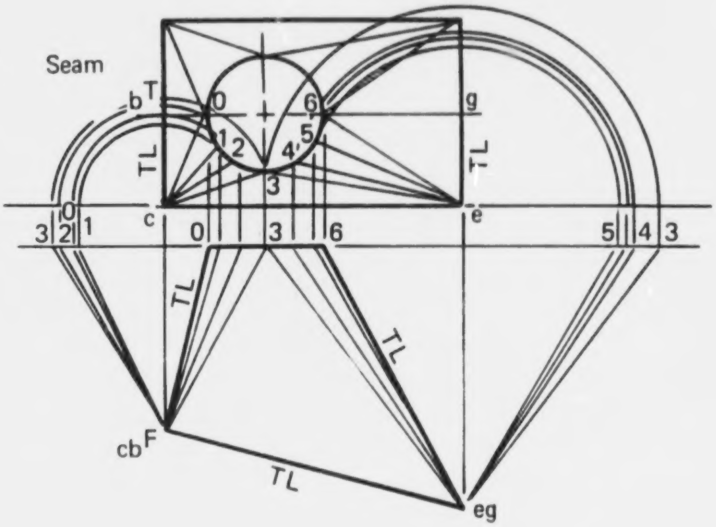


Note: This transition piece goes from a circular part to a rectangular part.

2. Divide the circle into equal parts (normally 15° to 30° increments).
3. Draw common elements in both views forming triangle surfaces from the circle to the rectangle.

Assignment Sheet 12

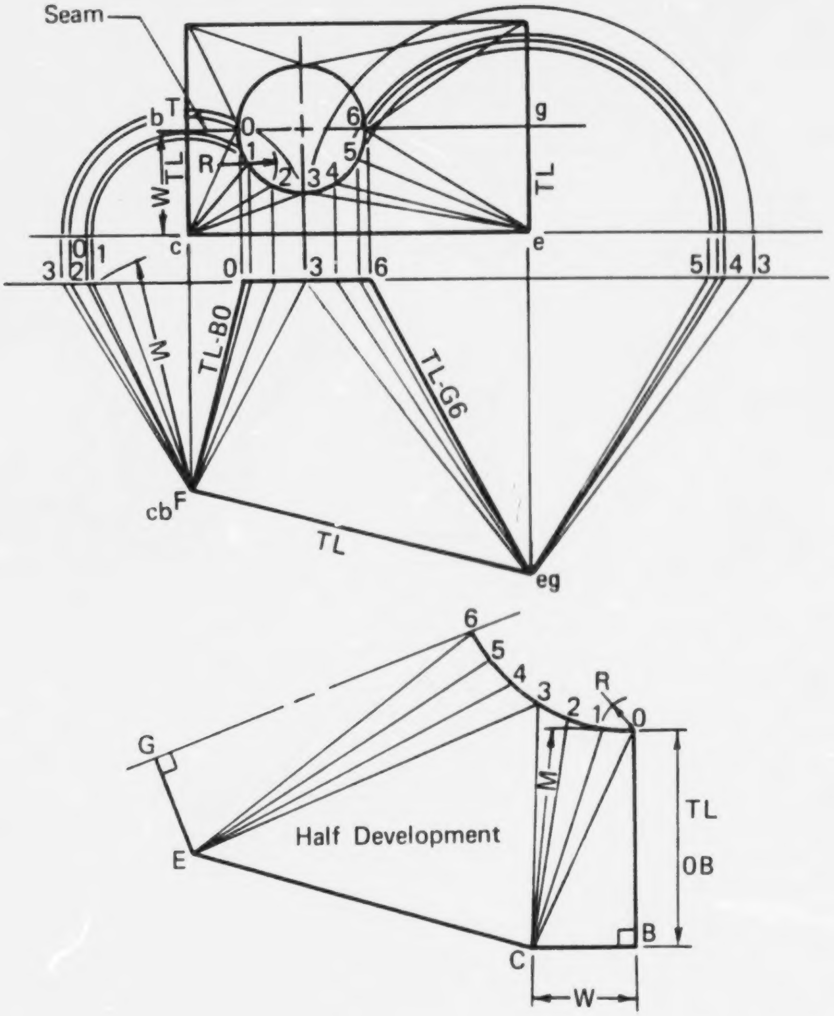
4. Observe the number of true lengths that must be found.


Seam
bT
0
6
g
1
2
4
5
3
TL
TL
c
e
3
2
0
1
0
3
6
5
4
3
TL
TL
cbF
TL
eg

5. Determine where seam will be; this should be the shortest connection.

Assignment Sheet 12

6. Construct TL of all elements by using a TL diagram or other means.


Seam
b
T
0
6
g
1
5
R
2
3
4
TL
W
TL
c
e
3
2
0
1
0
3
6
5
4
3
W
TL-B0
TL-G6
cbF
TL
eg
6
5
4
3
R
2
1
0
G
M
TL
Half Development
OB
E
B
C
W

7. Select an open area to start the development.

8. Starting with the seam, develop inside out by constructing triangles of each surface.

9. Take true length dimensions of each triangle from the chord distance on the circle, those TL given, and those found on the TL diagram.

10. Complete the development adding bend lines.

Assignment Sheet 12

Problems:

1. Construct each problem on a "B" size sheet of vellum or other media selected by instructor. Draw both the two view drawing and the development. Add dimensions as instructed.

2. Make a blueline print of the drawings and cut the pattern out with scissors.

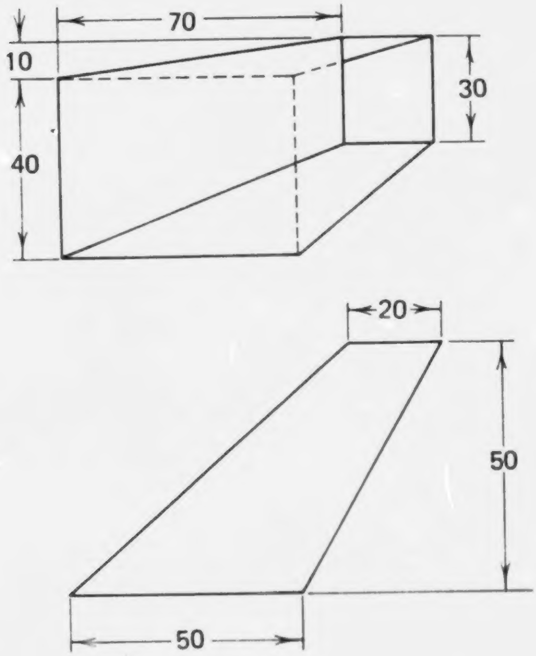
   Note: Half patterns will need to be doubled.

3. Tape or glue development together to form three dimensional part.

   Note: As an alternate, construct a #3D wire frame of each problem, and use an "unfold sheet metal" program to produce development.

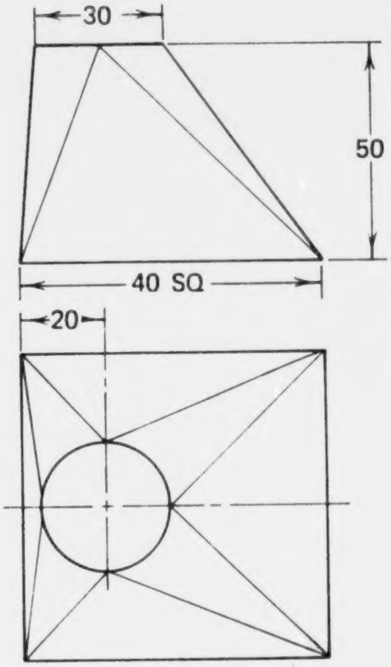
4. Hand in both the original and the object to your instructor.

A.



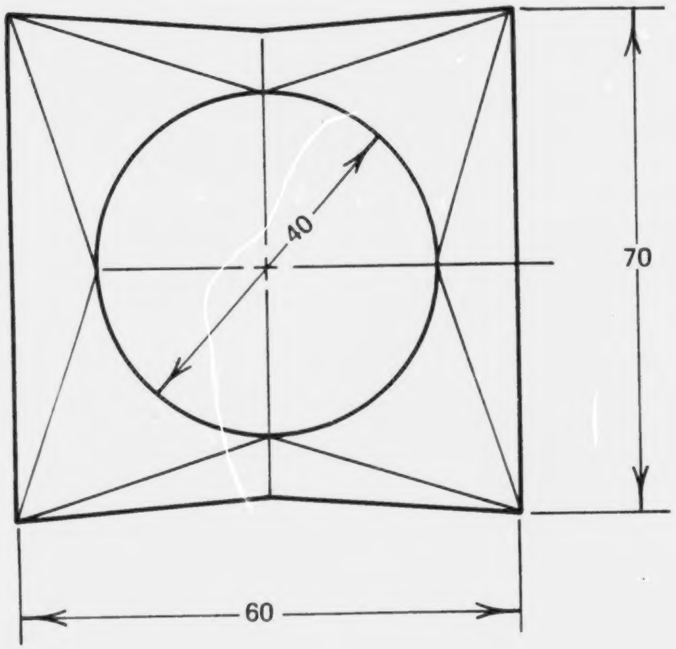
Assignment Sheet 12

B.

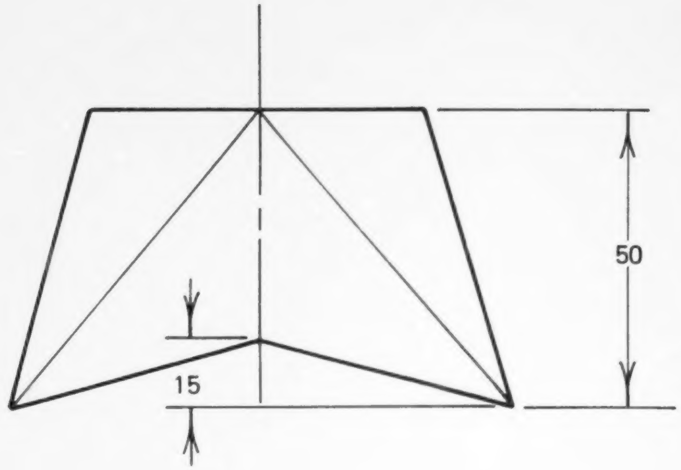


30
50
40 SQ
20

C.



Assignment Sheet 12



Power Transmission: Belts, Chains, and Fluid Power
Unit 10

Objective Sheet

Unit Objective

After completing this unit, the student should be able to select a chain drive and a V-belt drive. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to power transmission with their correct definitions.
2. Complete statements about chain drives and their advantages over gear drives.
3. Select true statements about gear drives and their advantages over chain drives..
4. Complete statements about chain drives and their advantages over belt drives..
5. Select major types of power transmission chains.
6. Complete statements about belt drives and their advantages over chain drives.
7. Solve problems about guidelines for selecting a V-belt drive..
8. Match basic hydraulic components with their functions.
9. Match basic pneumatic components with their functions..
10. Complete statements about air circuit components.
11. Select a chain drive. (Assignment Sheet 1)
12. Select V-belts for given applications. (Assignment Sheet 2)

Power Transmission: Belts, Chains, and Fluid Power
Unit 10

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for enrichment of exceptional students as well as accommodation of special needs students.
4. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of unit evaluation form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.
10. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of the written test. Add or modify test questions as needed.
13. Give written test.
14. Compile assignment sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignments.
15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Check industries in your area for firms that use gear, belt, or chain drives in their operations. Arrange for the class to visit the industry, and have students work as teams to prepare reports on the types of drives they see in operation. Skill area: **Group effectiveness skills, teamwork.**

2. Have samples or pictures of gear drives to demonstrate as you study Objective 3. Have students who prepared reports on gear drives make their reports to the class as you discuss this objective. Skill areas: **Foundation skills, writing, and communications skills, listening.**

3. Have samples of chain drives to demonstrate as you study Objectives 4 and 5. Have students who prepared reports on chain drives make their reports to the class as you discuss these objectives. Skill areas: **Foundation skills, writing, and communication skills, listening.**

4. Have samples of belt drives to demonstrate as you study Objectives 6 and 7. Have students who prepared reports on belt drives make their reports to the class as you discuss these objectives. Skill areas: **Foundation skills, writing, and communications skills, listening.**

5. If you have a robotics or instrumentation program at your school, arrange for students to visit so they can see an hydraulic or pneumatic (or both) system at work. Skill area: **Foundation skills, science.**

Suggested Activities

Resources Used in Developing This Unit

1. *Fundamentals of Service, Power Trains Compact Equipment.* Moline, IL: Deere & Company, 1993.
2. Giesecke, Frederick E. *Technical Drawing.* New York: Macmillan Publishing Company, 1992.
3. Jensen, Cecil, and Jay Helsel. *Engineering Drawing and Design.* New York: Gregg Division/McGraw-Hill Book Company, 1979.

Power Transmission: Belts, Chains, and Fluid Power
Unit 10

Answers to Assignment Sheets

Assignment Sheet 1

A. 1. Load classification—uniform
   2. Service factor = 1
      Input power—5 × 1 = 5 HP
   3. Using 100 RPM and 5 HP, select chain #80 from Chain selection table
   4. On HP Rating table and using 100 RPM and interpolation, select 16 teeth. 5 HP is approximately halfway between 4.70 (15 teeth) and 5.38 (17 teeth).
   5. Speed ratio — $\frac{100}{40} = 2.5$
   6. Larger sprocket 16 × 2.5 = 40 teeth or use Speed ratio table
   7. Answer is 15.528 center distance in pitch
      60 chain length in pitches
   8. Convert to inches
      15.528 (1) = 15.528″ center distance
      60 (1) = 60″ chain length
   9. 15.528″ center distance is within the 27″ center distance limitation

B. 1. Load classification under pumps rotary gear type—uniform load
   2. Service factor = 1
      Input power—3 × 1
   3. Chain selection table using 3 HP and 1200 RPM, select #35—3/8″ pitch chain number
   4. Using 1200 RPM and 3 HP, select 19 teeth from HP ratings table
   5. Speed ratio — $\frac{1200}{750} = 1.60$
   6. Larger sprocket 19 × 1.60 = 30.4 or use speed ratio table for similar results, and select 30 teeth
   7. Answer is 13.638 center distance in pitches
      52 chain length in pitches
   8. Convert to inches
      13.638 (.375) = 5.115″ center distance
      52 (.375) = 19.5″ chain length
   9. 19.5 center distance is not less than 12″ center distance limitation

Answers to Assignment Sheets

Assignment Sheet 2

A. Step 1: Service factor = 1.2 (from Table 1). Design HP = 10 HP × 1.2 or 12 HP.

Step 2: Belt cross section is AP-AX (from Table 2), using design HP of 12 HP and 1160 (faster shaft), minimum sheave diameter of 10 HP, 1160 RPM motors = 4 1/2" (from table 3).

Step 3: Using the 1160 RPM from Table 4, and driven speed of 351 RPM from Table 4, the Torque Flex belt is rated at 8.17 HP. Also from Table 4, the motor (driver) sheave diameter is listed at 5.8″ and the driven sheave diameter is 20.0″. Moving to the right of Table 4, the center distance is 44.0″, which indicates a B128 Torque Flex belt should be used. Just below the center distance of 44.0″ the correction factor is indicated in bold face and it is 1.03.

Step 4: Since we are using a Torque Flex belt rated at 8.17 HP, and we have a correction factor of 1.03, we multiply the 8.17 by 1.03 to arrive at 8.4151 HP. Now, we divide the design HP by the corrected HP, 12 divided by 8.4151, and this indicates that 1.426 belts will be required, and since 1.426 is greater than 1, 2 Torque Flex belts are required for the application.

B. Step 1: Service factor = 1.4 (from Table 1). Design HP = 25 HP × 1.4 = 35 HP.

Step 2: Belt cross section is BP-BX, using design HP of 35 HP and 1750 RPM (faster shaft), minimum sheave diameter of 25 HP, 1750 RPM motor = 4 1/2″ (from Table 3).

Step 3: Using the 1750 RPM from Table 4, and driven speed of 500 RPM from Table 4, the Sure Grip Premium belt is rated at 6.69 HP. Also from Table 4, the motor (driver) sheave diameter is listed as 5.0″ and the driven sheave diameter is 18.4″. Moving to the right of Table 4, the center distance is 30.2″, which indicates a B97 Sure Grip Premium belt should be used. Just below the center distance of 30.2″ the correction factor is listed in bold face and it is 0.95.

Step 4: Since we are using a Sure Grip Premium belt rated at 6.69 HP, and we have a correction factor of 0.95, we multiply 6.69 by .95 and get 6.35 HP. Since design HP is 35, we divide 35 by the corrected HP of 6.35, and we get 5.503. Since the 5.503 is greater than 5, 6 Sure Grip Premium belts are required for the application.

Power Transmission: Belts, Chains, and Fluid Power
Unit 10

Answers to Written Test

1.
   - a. 6
   - b. 3
   - c. 1
   - d. 9
   - e. 7
   - f. 8
   - g. 5
   - h. 4
   - i. 2

2.
   - a. Is not
   - b. Greater
   - c. Design changes
   - d. Shock
   - e. Faster

3. a, b

4.
   - a. No
   - b. Bearings
   - c. Install
   - d. Synchronizing
   - e. No
   - f. Elongation

5. a, c, e, f, g

6.
   - a. Belt dressing
   - b. Less
   - c. Distances
   - d. Extremely

7.
   - a. (3)
   - b. (3)

8.
   - a. 7
   - b. 5
   - c. 4
   - d. 1
   - e. 6
   - f. 3
   - g. 2

9.
   - a. 4
   - b. 3
   - c. 5
   - d. 1
   - e. 6
   - f. 2

10.
    - a. Two-way or three-way
    - b. Air motors

Power Transmission: Belts, Chains, and Fluid Power
Unit 10

Written Test

Name ______________________________ Date __________________ Score ____________

1. Match the terms on the right with their correct definitions.

______ a. Endless flexible belt on pulleys

______ b. Devices for slowing or stopping power drive shafts

______ c. Endless chain on sprocket

______ d. Devices for stopping or starting a machine without stopping the prime motor

______ e. Devices for joining shafts together

______ f. Devices used to transmit power around corner and different angles when the driver and driven shafts are not lined up

______ g. The use of liquid for power transmission

______ h. The use of compressed air for power transmission

______ i. Any device used to reduce the speed of the output device or driver

1. Chain drive
2. Speed reducer
3. Brakes
4. Pneumatics
5. Hydraulics
6. Belt drive
7. Couplings
8. Flexible shafts
9. Clutches

2. Complete statements about chain drives and their advantages over gear drives. Circle the information that best completes each of the following statements.

a. Center to center distance (**is not**) (**is**) restricted on chain drives.

b. Because of (**smaller**) (**greater**) tolerances, chain drives are easy to install.

c. Chain drives afford ease for (**most operating conditions**) (**design changes**).

d. Chain drives absorb (**wear**) (**shock**) better.

e. Chain drives wear longer and they are (**faster**) (**cleaner**) to change.

Written Test

3. Select true statements about gear drives and their advantages over chain drives. Place an "X" beside each true statement.

_______a. When space limitations are important, gear drives afford the shortest center to center distance.

_______b. Gear drives can have a greater maximum speed ratio and obtain a higher RPM.

_______c. At higher horsepower and RPM, gear drives are generally longer lasting.

4. Complete statements about chain drives and their advantages over belt drives. Circle the material that best completes each of the following statements.

a. Because a chain drive does not slip or creep, it loses (**minimal**) (**no**) power.

b. Because of slack, chain drives make lower loads on (**connecting shafts**) (**bearings**).

c. Chain drives occupy less overall space and are easier to (**install**) (**maintain**).

d. For (**synchronizing**) (**varying speeds of**) several shafts, chain drives are better.

e. Chain drives operate at higher temperatures, produce (**no**) (**little**) static electricity, and have virtually no fire hazard.

f. A chain drive does not deteriorate with age because of slower (**brittleization**) (**elongation**) due to wear.

5. Select major types of power transmission chains. Place an "X" beside each type of transmission chain in the following list.

_______a. Roller

_______b. Offset roller

_______c. Double pitch

_______d. Triple pitch

_______e. Detachable

_______f. Bead

_______g. Inverted tooth

Written Test

6. Complete statements about belt drives and their advantages over chain drives. Circle the information that best completes each of the following statements.

    a. Except for (**initial lubrication**) (**belt dressing**), belts require no lubrication for flexibility.

    b. Belts afford (**about the same**) (**less**) vibration and generally operate with less noise.

    c. Flat belts can be used for extremely long operating (**distances**) (**periods**).

    d. Belts in general can be used for (**relatively**) (**extremely**) high speeds.

7. Solve problems about guidelines for selecting a V-belt drive. Circle the item that best solves each of the following problems.

    a. You've been instructed to determine the size of a V-belt needed for a specific application. The very first thing you should do is:

        (1) Determine what the belt length will be.

        (2) Select all selection information from a normal duty table.

        (3) Determine whether the belt will be used on light, normal, or heavy duty equipment.

    b. A major part of your activity as part of your instructions in item a will be:

        (1) Selecting the outside diameter of the small V-pulley.

        (2) Selecting the outside diameter of the driven V-pulley.

        (3) Selecting the outside diameters of both the small V-pulley and the driven V-pulley.

8. Match basic hydraulic components with their functions. Place the number of the component in the blank beside the description of its function.

_______a. A reservoir to hold fluid

_______b. A device to force liquid through a system

_______c. Parts to control flow and pressure

1. Cylinder or motors
2. Gages
3. Accumulator
4. Valves

Written Test

______d. Device to covert fluid energy into mechanical force

______e. Parts that help clean system fluid

______f. A cylinder in which fluid is stored under pressure and used to meet fluctuating demands

______g. Instruments that measure pressure, temperature, or flow

5. Pump
6. Filters and strainers
7. Tank

9. Match basic pneumatic components with their functions. Place the number of the component in the blank beside the description of its function.

______a. Indicates pressure

______b. Removes dirt and water from system air

______c. Compresses system air

______d. Stores compressed air

______e. Maintains air pressure at an acceptable range

______f. Lubricates the operating components of a system

1. Receiving tank
2. Lubricator
3. Filter
4. Pressure gage
5. Compressor
6. Regulator

10. Complete statements about air circuit components. Circle the information that best completes each of the following statements.

a. Basic control elements in an air system are power valves which may be (**one-way or two-way**) (**two-way or three-way**) depending on system application.

b. Power elements in a system include cylinders and (**pistons**) (**air motors**).

***Permission to duplicate this test is granted.**

Power Transmission: Belts, Chains, and Fluid Power
Unit 10

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Select A Chain Drive Rating ______

Comments: ____

____

Assignment Sheet 2—Select A V-Belt Rating ______

Comments: ____

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

Teacher Signature ______________________________ Date __________

Student Signature ______________________________ Date __________

***Permission to duplicate this form is granted.**

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Power Transmission: Belts, Chains, and Fluid Power
Unit 10

Information Sheet

1. **Terms and definitions**

   a. **Belt drive** — Endless flexible belt on pulleys

   b. **Brakes** — Devices for slowing or stopping power drive shafts

   c. **Chain drive** — Endless chain on sprocket

   d. **Clutches** — Devices for stopping or starting a machine without stopping the prime motor

   e. **Couplings** — Devices for jointing shafts together

   f. **Flexible shafts** — Devices used to transmit power around corner and different angles when the driver and driven shafts are not lined up

   g. **Hydraulics** — The use of liquid for power transmission

   h. **Pneumatics** — The use of compressed air for power transmission

   i. **Speed reducer** — Any device used to reduce the speed of the output device or driver

2. **Chain drives and their advantages over gear drives**

   a. Center to center distance is not restricted on chain drives.

   b. Because of greater tolerances, chain drives are easy to install.

   c. Chain drives afford ease of design changes.

   d. Chain drives absorb shock better.

   e. Chain drives wear longer and they are faster to change.

3. **Gear drives and their advantages over chain drives**

   a. When space limitations are important, gear drives afford the shortest center to center distance.

   b. Gear drives can have a greater maximum speed ratio and obtain a higher **RPM**.

   c. At higher horsepower and RPM, gear drives are generally more practical.

Information Sheet

4. **Chain drives and their advantages over belt drives**

    a. Because a chain drive does not slip or creep, it loses no power.

    b. Because of slack, chain drives make lower loads on bearings.

    c. Chain drives occupy less overall space and are easier to install.

    d. For synchronizing several shafts, chain drives are better

    e. Chain drives operate at higher temperatures, produce no static electricity, and have virtually no fire hazard.

    f. A chain drive does not deteriorate with age because of slower elongation due to wear.

5. **Major types of power transmission chains**

    a. Roller

    b. Offset sidebar

    c. Double pitch

    d. Pintle

    e. Detachable

    f. Bead

    g. Inverted tooth

6. **Belt drives and their advantages over chain drives**

    a. Except for belt dressing, belts require no lubrication for flexibility.

    b. Belts afford less vibration and generally operate with less noise.

    c. Flat belts can be used for extremely long operating distances.

    d. Belts in general can be used for extremely high speeds.

Information Sheet

7. **Guidelines for selecting a V-belt drive**

   a. Decide whether the belt will be used on light, normal, or heavy duty equipment.

      Note: Refer to the items in Student Supplement 1 and to examples in Assignment Sheet 2 to help you follow these steps properly.

   b. If the belt is for light duty, multiply the horsepower rating by 1.20; then use normal duty tables.

      Example: Light duty equipment includes dishwashers, clotheswashers, fans, and blowers.

   c. If the belt is for formal duty, use normal duty tables.

      Example: Normal duty equipment includes drill presses, power lawn mowers, heating and ventilating fans, generators, and buffers.

   d. If the belt is for heavy duty, multiply the horsepower rating by .85; then use normal duty tables.

      Note: Heavy duty equipment includes metal working machines, compressors, lathes, grinders, and industrial machines.

   e. Select the outside diameter of the small V-pulley.

   f. Select driven V-pulley diameter.

   g. Determine the belt length.

8. **Basic hydraulic components and their functions**

   a. **Tank**—A reservoir to hold fluid

   b. **Pump**—A device to force liquid through a system

   c. **Valves**—Parts to control flow and pressure

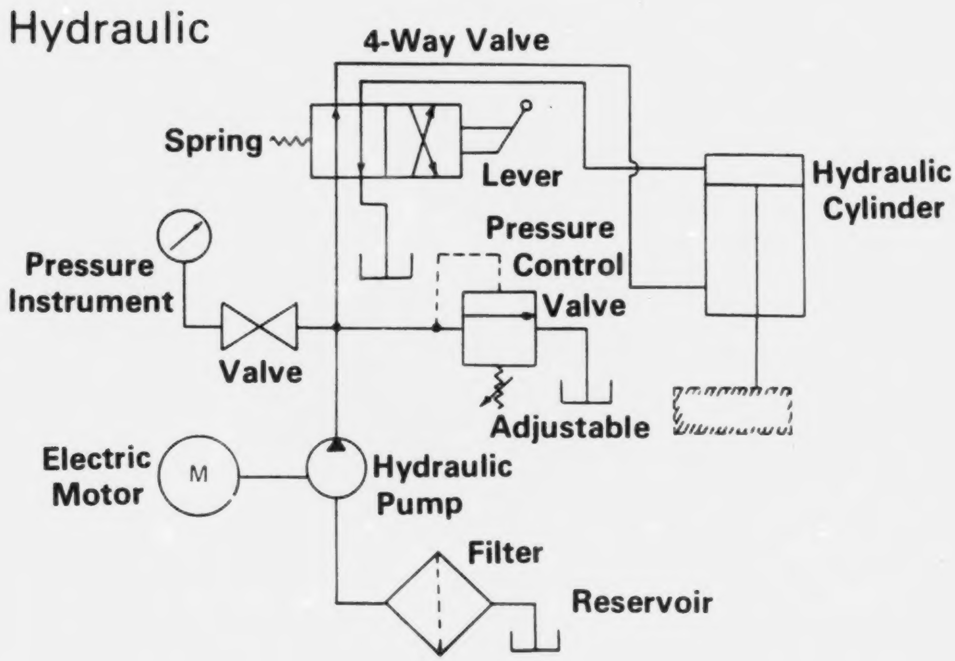
   d. **Cylinder or motor**—Device to convert fluid energy into mechanical force

   e. **Filters and strainers**—Parts that help clean system fluid

   f. **Accumulator**—A cylinder in which fluid is stored under pressure and used to meet fluctuating demands

Information Sheet

g. **Gages**—Instruments that measure pressure, temperature, or flow


Hydraulic
4-Way Valve
Spring
Lever
Hydraulic Cylinder
Pressure Control Valve
Pressure Instrument
Valve
Adjustable
Electric Motor
M
Hydraulic Pump
Filter
Reservoir

9. **Basic pneumatic components and their functions**

   a. **Pressure gage**—Indicates pressure

   b. **Filter**—Removes dirt and water from system air

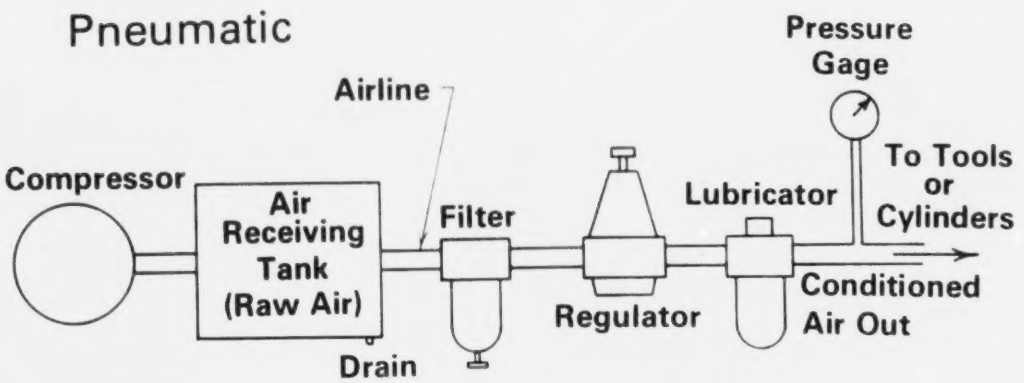
   c. **Compressor**—Compresses system air

   d. **Receiving tank**—Stores compressed air

   e. **Regulator**—Maintains air pressure at an acceptable range

Information Sheet

f. **Lubricator**—Lubricates the operating components of a system


Pneumatic
Pressure Gage
Airline
To Tools or Cylinders
Compressor
Air Receiving Tank (Raw Air)
Filter
Lubricator
Conditioned Air Out
Regulator
Drain

10. **Air circuit components**

    a. Basic control elements in an air system are power valves which may be two-way or three-way depending on system application.

    b. Power elements in a system include cylinders and air motors.

Power Transmission: Belts, Chains, and Fluid Power
Unit 10

Assignment Sheet 1—Select A Chain Drive

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Correct data for Problem A	_____
Correct data for Problem B	_____

Directions: In order to select a chain drive, you will need the charts which are included at the end of this assignment sheet. Use the following example as a guideline for solving the problems.

Example problem: Select a roller chain drive to transmit 5 HP from a countershaft to the main shaft of a barking drum of a paper mill. The input is an electric motor operating a countershaft at 1200 RPM. Both shafts are 1.5" in diameter to be located approximately 22½" from center to center. The barking drum puts uneven demands on the output shaft. A design of 378 to 382 RPM on the output is needed.

Example solution:

1. Determine load classification:
   a. Go to load classification chart (Table 1).
   b. Locate paper mills.
   c. Under paper mills, locate barking drum.
   d. Read to the right under the load classification column to find "heavy shock."

      Note: Uneven demands on the output shaft help to classify it as heavy shock.
2. Determine service factor:
   a. Go to service factor chart (Table 2).
   b. Under load classification, find heavy shock.
   c. Read to the left under electric motor for the service factor of 1.5.

Assignment Sheet 1

3. Determine design HP:

   a. Multiply the application of horsepower by the service factor to obtain equivalent design HP.

   b. 5 × 1.5 = 7.5 HP.

   Note: For stainless steel chains, multiply the design HP by a factor from the application condition table—Table 3.

4. Determine chain size:

   a. Go to chain selection table (Table 4).

   b. Find the intersection of the columns of design horsepower at 7 1/2 and RPM of smaller sprocket at 1200.

   Note: 1200 RPM falls into the category of 1150-1399 RPM.

   c. Chain size is #40.

5. Determine minimum size sprocket:

   a. Go to HP ratings for ANSI roller chains table (Table 5).

   b. Using chart for No. 40 and 1/2″ pitch, read down 1200 RPM column to 7.27.

   Note: This is as close to your design HP of 7.5 as there is.

   c. Read left on 7.27 column to 19 teeth.

   Note: Check the maximum bore to accomodate the 1 1/2″ shafts.

6. Calculate speed ratio:

   a. $$\frac{\text{Maximum input RPM}}{\text{Maximum output RPM}} = \frac{1200\text{ RPM}}{382\text{ RPM}}$$

   b. Speed ration is 3.12 RPM minimum.

Assignment Sheet 1

7. Find center distance and length:

   a. Using Speed ratio chart (Table 6), read down teeth on driver sprocket column to 19.

   b. Read across ratio on 19 to a number close to your ratio of 3.12; this is 3.16 on the chart.

   c. Read up from 3.12 to see that there are 60 teeth on the driven sprocket.

   d. Center distance (CD) in same box with 3.12 is 23.332.

   e. Length in same box with 3.12 is 88.

   Note: Center distance and length are expressed in pitches in this chart. You will need to convert these to feet or inches.

8. Convert pitches to inches:

   a. Length × pitch = 88 × 1/2.

   b. Chain length in inches = 44″.

   c. Center distance × pitch = 23.332 × 1/2.

   d. Center distance ininches = 11.67″.

   Note: Stop here if center to center distance is not important.

9. Calculate chain length for center to center distance:

   a. Since a set center distance has been established of 22 1/2″ in this problem, the following calculations must be made to determine the chain length.

   b. Chain length in pitches = $\dfrac{2\ (\text{set center distance})}{\text{Pitch}}$ +

$$\frac{\text{Total number teeth on both sprockets} + \text{constant}^{*}}{2}$$

*Constant
If ratio is up to 4:1, use 2
4 to 6:1, use 4
6 to 8:1, use 6

Note: Ratio in this example is 3.12 which is up to 4:1, so use 2.

Assignment Sheet 1

c. Chain length in pitches $= \frac{2\ (22.5)}{.5} + \frac{19 + 60}{2} + 2$

$$= \frac{45.0}{.5} + \frac{79}{.2} + 2$$

$$= 90 + 39.5 + 2 = 131.5$$

Note: Round to 132 pitches since 22 1/2 center distance is not absolutely critical.

d. Chain length in inches = Chain length in pitches × pitch

= 132 (.5)

= 66″ chain length at 22.5″ approximate center distance.

Note: It must be remembered that more than one combination of sockets and chain will give acceptable results.

Problems:

A. A conveyor belt, uniformly loaded is to be driven at approximately 40 RPM by a speed reducer powered by a 5 HP electric motor. The output shaft is 1 5/8″ diameter reduced to 100 RPM by a speed reducer. The shaft diameter of the conveyor belt is 1 7/8″. Select a center distance of not greater than 27″. Select a chain length and center distance.

B. A rotary gear type of lubrication pump in a hydraulic press is driven from a 1 3/8″ diameter shaft at 750 RPM. The driver rated at 3 HP has a shaft diameter of 1 1/4″ operating at 1200 RPM. Center distance must not be less than 12″. Select a center distance and belt length.

Assignment Sheet 1

Table 1
Load Classification Chart

Type of Machine to be driven	Table #1 Load Classification	Table #2 Class of Service Number	
	For Helical Base-Mounted Reductors, Worm Gear Reductors & Ratiomotors and Roller Chain-Drives	For Helical Shaft-Mounted Reductors & Ratiomotors and Base-Mounted Ratiomotors	
		3 to 10 hours/day service	Over 10 hours/day service
Agitators			
Pure Liquids	Uniform	I	II
Liquids and Solids	Moderate Shock	II	II
Liquids – Variable Density	Moderate Shock	II	II
Blowers			
Centrifugal	Uniform	I	II
Lobe	Moderate Shock	II	II
Vane	Uniform	I	II
Brewing and Distilling			
Bottling Machinery	Uniform	I	II
Brew Kettles – Continuous Duty	Uniform	–	II
Cookers – Continuous Duty	Uniform	–	II
Mash Tubs – Continuous Duty	Uniform	–	II
Scale Hopper – Frequent Starts	Moderate Shock	II	II
Can Filling Machines	Uniform	I	II
Cane Knives	Moderate Shock	II	II
Car Dumpers	Heavy Shock	III	–
Car Pullers	Moderate Shock	I	–
Clarifiers	Uniform	I	II
Classifiers	Moderate Shock	II	II
Clay Working Machinery			
Brick Press	Heavy Shock	III	III
Briquette Machine	Heavy Shock	III	III
Clay Working Machinery	Moderate Shock	II	II
Pug Mill	Moderate Shock	II	II
Compressors			
Centrifugal	Uniform	I	II
Lobe	Moderate Shock	II	II
Reciprocating, Multi-cylinder	Moderate Shock	II	II
Reciprocating, Single-cylinder	Heavy Shock	III	III
Conveyors – Uniformly Loaded or Fed			
Apron or Assembly	Uniform	I	II
Belt, Bucket or Chain	Uniform	I	II
Flight	Uniform	I	II
Oven or Screw	Uniform	I	II
Conveyors – Heavy Duty not Uniformly Fed			
Apron	Moderate Shock	II	II
Assembly	Moderate Shock	II	II
Belt, Bucket or Chain	Moderate Shock	II	II
Flight or Oven	Moderate Shock	II	II
Reciprocating or Shaker	Heavy Shock	III	III
Screw	Moderate Shock	II	II
Crusher			
Ore	Heavy Shock	III	III
Stone	Heavy Shock	III	III
Elevators			
Bucket – Uniform Load	Uniform	I	II
Bucket – Heavy Load	Moderate Shock	II	III
Bucket – Continuous Duty	Uniform	I	II
Centrifugal Discharge	Uniform	I	II
Freight	Moderate Shock	II	II
Gravity Discharge	Uniform	I	II
Feeders			
Apron or Belt	Moderate Shock	II	II

Courtesy of Boston Gear/Incom Internation Inc.

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Assignment Sheet 1

Table 1 (Continued)
Load Classification Chart

Type of Machine to Be Driven	Table #1 Load Classification	Table #2 Class of Service Number	
	For Helical Base-Mounted Reductors, Worm Gear Reductors & Ratiomotors and Roller Chain-Drives	For Helical Shaft-Mounted Reductors & Ratiomotors and Base-Mounted Ratiomotors	
		3 to 10 hours/day service	Over 10 hours/day service
Disc	Uniform	I	II
Reciprocating	Heavy Shock	III	III
Screw	Moderate Shock	II	II
Food Industry			
Best Slicer	Moderate Shock	II	II
Cereal Cooker	Uniform	I	II
Dough Mixer or Meat Grinder	Moderate Shock	II	II
Generators (not welding)	Uniform	I	II
Hammer Mills	Heavy Shock	III	III
Hoists			
Heavy Duty	Heavy Shock	III	III
Medium Duty or Skip Type	Moderate Shock	II	II
Laundry Tumblers	Moderate Shock	II	III
Line Shafts			
Heavy Shock Load	Heavy Shock	III	III
Moderate Shock Load	Moderate Shock	II	II
Uniform Load	Uniform	I	I
Machine Tools			
Bending Roll	Moderate Shock	II	II
Punch Press - Gear Driven	Heavy Shock	III	III
Plate Planers	Heavy Shock	III	III
Tapping Machine	Heavy Shock	III	III
Other Machine Tools			
Main Drives	Moderate Shock	II	II
Auxiliary Drives	Uniform	I	II
Metal Mills			
Draw Bench Carriage and Main Drive	Heavy Shock	III	III
Slitters	Moderate Shock	II	II
Table Conveyors			
Non-Reversing	Moderate Shock	II	III
Reversing	Moderate Shock	—	III
Wire Drawing and Flattening Machine	Moderate Shock	II	III
Wire Winding Machine	Moderate Shock	II	II
Mills, Rotary Type			
Ball	Heavy Shock	III	III
Dryers and Coolers	Moderate Shock	II	II
Kilns	Moderate Shock	II	II
Pebble	Heavy Shock	III	III
Rod, Plain and Wedge Bar	Heavy Shock	III	III
Mixers			
Concrete Mixers			
Continuous Duty	Moderate Shock	II	II
Intermittent Duty	Moderate Shock	I	—
Constant Density	Uniform	I	II
Variable Density	Moderate Shock	II	II
Paper Mills			
Agitators (Mixers)	Moderate Shock	II	II
Barker — Auxiliaries — Hydraulic	Moderate Shock	—	III
Barker — Mechanical	Moderate Shock	—	III
Barking Drum	Heavy Shock	—	III
Beater and Pulper	Moderate Shock	—	II
Bleacher	Uniform	—	II
Calendars	Moderate Shock	—	II
Calendars — Super	Moderate Shock	—	II
Converting Machine, Except Cutters, Platers	Moderate Shock	—	II
Conveyors	Uniform	—	II
Couch	Moderate Shock	—	II

Courtesy of Boston Gear/Incom Internation Inc.

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Assignment Sheet 1

Table 1 (Continued)
Load Classification Chart

Type of Machine to Be Driven	Table #1 Load Classification	Table #2 Class of Service Number	
	For Helical Base-Mounted Reductors, Worm Gear Reductors & Ratiomotors and Roller Chain-Drives	For Helical Shaft-Mounted Reductors & Ratiomotors and Base-Mounted Ratiomotors	
		3 to 10 hours/day service	Over 10 hours/day service
Cutters — Platers	Heavy Shock	—	III
Cylinders or Dryers	Moderate Shock	—	II
Felt Stretcher	Moderate Shock	—	II
Felt Whipper	Heavy Shock	—	III
Jordans	Uniform	—	II
Log Haul	Heavy Shock	—	III
Presses	Uniform	—	II
Pulp Machine Reel	Moderate Shock	—	II
Stock Chests	Moderate Shock	—	II
Suction Roll	Uniform	—	II
Washers and Thickeners	Moderate Shock	—	II
Winders	Uniform	—	II
Printing Presses	Uniform	I	II
Pullers			
Barge Haul	Heavy Shock	III	III
Pumps			
Centrifugal	Uniform	I	II
Proportioning	Moderate Shock	II	II
Reciprocating			
Single Acting, 3 or more Cylinders	Moderate Shock	II	II
Double Acting, 2 or more Cylinders	Moderate Shock	II	II
Rotary — Gear, Lobe, or Vane Type	Uniform	I	II
Rubber and Plastics Industries			
Mixing Mills	Heavy Shock	III	III
Rubber Calendars or Sheeters	Moderate Shock	II	II
Sewage Disposal Equipment			
Bar Screens	Uniform	I	II
Chemical Feeders	Uniform	I	II
Collectors	Uniform	I	II
Dewatering Screens	Moderate Shock	II	II
Scum Breakers	Moderate Shock	II	II
Slow or Rapid Mixers	Moderate Shock	II	II
Thickeners	Moderate Shock	II	II
Vacuum Filters	Moderate Shock	II	II
Screens			
Air Washing	Uniform	I	II
Rotary — Stone or Gravel	Moderate Shock	II	II
Traveling Water Intake	Uniform	I	II
Slab Pushers	Moderate Shock	II	II
Stokers	Uniform	I	II
Textile Industry			
Batchers or Calendars	Moderate Shock	II	II
Cards	Moderate Shock	II	II
Dyeing Machinery or Dryers	Moderate Shock	II	II
Looms, Mangles, Nappers or Pads	Moderate Shock	II	II
Slashers or Soapers	Moderate Shock	II	II
Spinners	Moderate Shock	II	II
Tenters Frames	Moderate Shock	II	II
Washers or Winders	Moderate Shock	II	II
Tumbling Barrels	Heavy Shock	III	III
Windlass	Moderate Shock	II	II

Table 2
Service Factor Table

Load Classification	TYPE OF INPUT POWER		
	Internal Combustion Engine With Hydraulic Drive	Electric Motor With Mechanical Drive	Internal Combustion Engine With Mechanical Drive
Uniform	1.0	1.0	1.2
Moderate Shock	1.2	1.3	1.4
Heavy Shock	1.4	1.5	1.7

Courtesy of Boston Gear/Incom International Inc.

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Assignment Sheet 1

Table 3
Application Conditions Table for Stainless Steel Chains

Application Conditions	Factor
Wet	2.0
Dry	5.0

Table 4
Selection Chart

BOSTON ROLLER CHAIN SELECTION TABLE

RPM of Smaller Sprocket	DESIGN HORSEPOWER												
	1/2	1	1-1/2	2	3	4	5	7-1/2	10	15	20	25	30
	CHAIN NUMBER												
1700–2000	41	41	35	35	35	35	35	40	40	40	40–2	40–2	40–3
1400–1699	41	41	41	35	35	35	40	40	40	50	50	50–2	50–2
1150–1399	41	41	41	41	35	35	40	40	50	50	60	60	80
950–1149	41	41	41	41	35	40	40	50	50	60	60	80	80
800–949	41	41	41	41	40	40	40	50	50	60	60	80	80
650–799	41	41	41	41	40	40	40	50	50	60	80	80	80
525–649	41	41	41	40	40	40	50	50	60	80	80	80	80
425–524	41	41	40	40	40	50	50	60	60	80	80	80	100
375–424	41	41	40	40	40	50	50	60	60	80	80	100	100
325–374	41	41	40	40	50	50	50	60	80	80	80	100	100
275–324	41	40	40	40	50	50	60	60	80	80	80	100	100
225–274	41	40	40	40	50	60	60	80	80	80	100	100	120
185–224	41	40	40	50	50	60	60	80	80	100	100	120	120
160–184	41	40	50	50	60	60	80	80	80	100	100	120	120
140–159	41	40	50	50	60	60	80	80	80	100	120	120	120
120–139	40	40	50	50	60	80	80	80	100	100	120	120	140
90–119	40	50	50	60	80	80	80	100	100	120	120	140	140
75–89	40	50	60	60	80	80	80	100	100	120	140	140	160
65–74	40	50	60	60	80	80	80	100	100	120	140	160	160
55–64	40	50	60	80	80	80	100	100	120	140	140	160	
45–54	50	60	60	80	80	100	100	120	120	140	160	160	
35–44	50	60	80	80	100	100	100	120	140	160	160		
31–34	50	60	80	80	100	100	120	120	140	160	160		
26–30	50	80	80	80	100	100	120	140	140	160			
21–25	60	80	80	100	100	120	120	140	160	160			
16–20	60	80	100	100	120	120	140	160	160				
11–15	80	80	100	120	140	140	140	160					
5–10	80	100	120	140	160	160							

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Assignment Sheet 1

Table 5
HP Ratings for ANSI Roller Chains Table

Small Sprocket		HP RATINGS – STANDARD SINGLE* STRAND ROLLERLESS CHAIN – NO. 25 – 1/4" PITCH																			
RPM → Teeth	P.D.	10	20	30	50	75	100	125	150	200	250	300	400	600	900	1200	1800	2500	3000	3500	4000
12	.97"	.007	.014	.020	.032	.046	.059	.072	.085	.11	.14	.16	.21	.29	0.43	0.55	0.80	1.07	1.26	1.45	1.62
15	1.20	.009	.018	.025	.040	.058	.075	.092	.108	.14	.17	.20	.26	.38	0.54	0.70	1.01	1.36	1.61	1.85	2.08
17	1.36	.011	.020	.029	.046	.066	.086	.105	.124	.16	.20	.23	.30	.43	0.62	0.81	1.16	1.56	1.84	2.11	2.38
19	1.52	.012	.023	.033	.052	.075	.097	.119	.140	.18	.22	.26	.34	.49	0.70	0.91	1.31	1.76	2.07	2.38	2.69
20	1.60	.013	.024	.035	.055	.079	.103	.125	.148	.19	.23	.28	.36	.52	0.74	0.96	1.38	1.86	2.19	2.52	2.84
Lubrication *		Type I														Type II					

Small Sprocket		HP RATINGS – STANDARD SINGLE* STRAND ROLLERLESS CHAIN – NO. 35 – 3/8" PITCH																		
RPM → Teeth	P.D.	10	20	30	50	75	100	125	150	200	250	300	400	600	900	1200	1500	1800	2500	3000
11	1.33"	.023	.043	.062	.098	.14	.18	.22	.26	.34	.42	.49	.63	.91	1.32	1.72	2.08	2.4[illegible]	3.32	2.93
13	1.57	.027	.051	.074	.117	.17	.22	.27	.31	.41	.50	.59	.76	1.09	1.59	2.05	2.49	2.96	3.98	3.76
15	1.80	.032	.060	.086	.136	.20	.26	.31	.37	.47	.58	.68	.89	1.28	1.85	2.40	2.91	3.45	4.64	4.66
17	2.04	.037	.068	.099	.156	.22	.29	.36	.42	.54	.66	.78	1.02	1.46	2.12	2.75	3.33	3.95	5.31	5.63
19	2.28	.042	.077	.111	.176	.25	.33	.40	.47	.61	.75	.88	1.15	1.65	2.39	3.10	3.76	4.46	5.99	6.65
21	2.52	.046	.086	.124	.196	.28	.37	.45	.53	.68	.83	.98	1.27	1.84	2.66	3.45	4.19	4.97	6.68	7.73
23	2.75	.051	.095	.137	.217	.31	.41	.49	.58	.75	.92	1.09	1.41	2.03	2.94	3.81	4.62	5.48	7.37	8.68
25	2.99	.055	.104	.150	.237	.34	.44	.54	.64	.82	1.01	1.19	1.54	2.22	3.21	4.16	5.06	6.00	8.06	9.50
Lubrication *		Type I											Type II					Type III		

Small Sprocket		HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 41 – 1/2" PITCH																
RPM → Teeth	P.D.	10	20	30	50	75	100	125	150	200	250	300	400	600	900	1200	1800	2400	3000
11	1.77"	.030	.056	.080	.13	.18	.24	.29	.34	.44	.54	.64	.82	1.19	1.71	1.71	0.93	0.60	0.43
13	2.09	.036	.067	.096	.15	.22	.28	.35	.41	.53	.65	.76	.99	1.42	2.05	2.20	1.20	0.78	0.56
15	2.40	.042	.078	.112	.18	.26	.33	.40	.48	.62	.75	.89	1.15	1.66	2.39	2.73	1.49	0.96	0.69
17	2.72	.048	.089	.128	.20	.29	.38	.46	.55	.71	.86	1.02	1.32	1.90	2.74	3.29	1.79	1.16	0.83
19	3.04	.054	.100	.145	.23	.33	.43	.52	.62	.80	.97	1.15	1.49	2.14	3.09	3.89	2.12	1.38	0.98
21	3.35	.060	.112	.161	.26	.37	.48	.58	.69	.89	1.09	1.28	1.66	2.39	3.44	4.46	2.46	1.60	1.14
23	3.67	.066	.124	.178	.28	.41	.53	.64	.76	.98	1.20	1.41	1.83	2.64	3.79	4.92	2.82	1.83	1.31
25	3.99	.072	.135	.195	.31	.44	.58	.70	.83	1.07	1.31	1.55	2.00	2.88	4.15	5.38	3.20	2.08	1.49
Lubrication *		Type I								Type II					Type III		Type IV		

Small Sprocket		HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 43 – 1/2" PITCH																
RPM → Teeth	P.D.	10	20	30	40	50	75	100	125	150	175	200	250	300	350	400	500	600	900
11	1.77"	.030	.056	.080	.11	.13	.18	.24	.29	.34	.39	.44	.54	.64	.73	.82	1.01	1.19	1.40
13	2.09	.036	.067	.096	.13	.15	.22	.28	.35	.41	.47	.53	.65	.76	.87	.99	1.21	1.42	1.70
15	2.41	.042	.078	.112	.15	.18	.26	.33	.40	.48	.55	.62	.75	.89	1.02	1.15	1.41	1.66	2.00
16	2.56	.045	.084	.120	.16	.19	.28	.36	.43	.52	.59	.67	.81	.96	1.10	1.23	1.51	1.78	2.28
18	2.88	.051	.095	.137	.18	.22	.31	.41	.49	.59	.67	.76	.92	1.09	1.25	1.41	1.72	2.02	2.80
20	3.20	.057	.106	.153	.20	.25	.35	.46	.55	.66	.75	.85	1.03	1.22	1.40	1.58	1.93	2.27	3.25
22	3.51	.063	.118	.170	.23	.27	.39	.51	.61	.73	.83	.94	1.15	1.35	1.55	1.75	2.14	2.52	3.62
24	3.83	.069	.130	.187	.25	.30	.43	.56	.67	.80	.91	1.03	1.26	1.48	1.70	1.92	2.35	2.76	3.97
Lubrication *		Type I												Type II					Type III

RATINGS FOR INTERMEDIATE NUMBERS OF TEETH OR RPM MAY BE OBTAINED BY INTERPOLATION.

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Table 5 (Continued)

Small Sprocket		HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 40 – 1/2" PITCH																			
RPM →		10	20	30	50	75	100	125	150	200	250	300	400	500	600	900	1200	1500	1800	2400	3000
Teeth	P D																				
11	1.77"	.054	.10	.15	.23	.33	.43	.53	.62	.80	.98	1.16	1.50	1.84	2.16	3.11	4.03	4.93	4.66	3.03	2.17
13	2.09	.065	.12	.17	.28	.40	.52	.63	.74	.96	1.18	1.39	1.80	2.20	2.59	3.73	4.83	5.91	5.99	3.89	2.79
15	2.40	.076	.14	.20	.32	.46	.60	.74	.87	1.12	1.37	1.62	2.10	2.56	3.02	4.35	5.64	6.89	7.43	4.82	3.45
17	2.72	.087	.16	.23	.37	.53	.69	.84	.99	1.29	1.57	1.85	2.40	2.94	3.45	4.98	6.45	7.89	8.96	5.82	4.17
19	3.04	.098	.18	.26	.42	.60	.78	.95	1.12	1.45	1.77	2.09	2.71	3.31	3.90	5.62	7.27	8.89	10.5	6.88	4.92
21	3.35	.109	.20	.29	.46	.67	.87	1.06	1.25	1.62	1.98	2.33	3.02	3.69	4.34	6.26	8.11	9.91	11.7	7.99	5.72
23	3.67	.120	.22	.32	.51	.74	.96	1.17	1.38	1.78	2.18	2.57	3.33	4.07	4.79	6.90	8.94	10.9	12.9	9.16	6.55
25	3.99	.132	.25	.35	.56	.81	1.05	1.28	1.51	1.95	2.38	2.81	3.64	4.45	5.24	7.55	9.78	12.0	14.1	10.4	7.43
Lubrication •		Type I								Type II						Type III		Type IV			

Small Sprocket		HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 50 – 5/8" PITCH																			
RPM →		10	20	30	50	75	100	125	150	200	250	300	400	600	900	1200	1500	1800	2100	2400	2700
Teeth	P D																				
11	2.22"	.11	.20	.28	.45	.65	.84	1.03	1.21	1.56	1.91	2.25	2.92	4.21	6.07	7.86	7.44	5.58	4.42	3.62	3.04
13	2.61	.13	.24	.34	.54	.78	1.01	1.23	1.45	1.87	2.29	2.70	3.50	5.04	7.26	9.42	9.56	7.17	5.67	4.65	3.90
15	3.02	.15	.28	.40	.63	.90	1.17	1.43	1.69	2.19	2.67	3.15	4.08	5.88	8.48	11.0	11.9	8.89	7.03	5.76	4.83
17	3.40	.17	.32	.45	.72	1.04	1.34	1.64	1.93	2.50	3.06	3.60	4.67	6.73	9.70	12.6	14.3	10.7	8.48	6.95	5.83
19	3.80	.19	.36	.51	.81	1.17	1.51	1.85	2.18	2.82	3.45	4.06	5.27	7.59	10.9	14.2	16.9	12.7	10.0	8.22	6.89
21	4.19	.21	.40	.57	.90	1.30	1.69	2.06	2.43	3.15	3.85	4.53	5.87	8.46	12.2	15.8	19.3	14.7	11.6	9.55	8.01
23	4.59	.23	.44	.63	1.00	1.44	1.86	2.27	2.68	3.47	4.24	5.00	6.48	9.33	13.4	17.4	21.3	16.9	13.3	10.9	9.18
25	4.99	.26	.48	.69	1.09	1.57	2.04	2.49	2.93	3.80	4.64	5.47	7.09	10.2	14.7	19.1	23.3	19.1	15.1	12.4	10.4
Lubrication •		Type I					Type II						Type III				Type IV				

Small Sprocket		HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 60 – 3/4" PITCH																				
RPM →		10	20	30	50	75	100	125	150	200	250	300	400	600	900	1200	1400	1600	1800	2000	2200	2400
Teeth	P D																					
11	2.66"	.18	.34	.49	.78	1.11	1.44	1.76	2.07	2.69	3.29	3.87	5.02	7.23	10.5	11.9	9.45	7.70	6.49	5.51	4.78	4.20
13	3.13	.22	.41	.58	.93	1.33	1.72	2.11	2.48	3.22	3.94	4.64	6.01	8.65	12.5	15.3	12.1	9.89	8.34	7.08	6.14	5.39
15	3.61	.25	.47	.68	1.08	1.55	2.01	2.46	2.90	3.76	4.59	5.41	7.01	10.1	14.6	18.9	15.0	12.3	10.3	8.77	7.61	6.68
17	4.08	.29	.54	.78	1.24	1.78	2.30	2.82	3.32	4.31	5.26	6.20	8.03	11.6	16.7	21.7	18.2	14.8	12.5	10.6	9.18	8.06
19	4.56	.33	.61	.88	1.40	2.01	2.60	3.18	3.74	4.86	5.93	6.99	9.05	13.0	18.8	24.4*	21.5	17.5	14.7	12.5	10.9	9.52
21	5.03	.37	.68	.98	1.56	2.24	2.89	3.54	4.17	5.41	6.61	7.78	10.1	14.5	21.0	27.2	24.9	20.3	17.1	14.5	12.6	11.1
23	5.51	.40	.75	1.08	1.72	2.47	3.19	3.91	4.60	5.97	7.29	8.59	11.1	16.0	23.2	30.2	28.6	23.3	19.6	16.7	14.4	12.7
25	5.98	.44	.82	1.18	1.88	2.70	3.49	4.28	5.04	6.53	7.98	9.40	12.2	17.5	25.4	32.9	32.4	26.4	22.3	18.9	16.4	14.4
Lubrication •		Type I				Type II					Type III				Type IV							

Small Sprocket		HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 80 – 1" PITCH																				
RPM →		10	20	30	50	75	100	125	150	200	250	300	400	600	900	1000	1200	1400	1600	1800	2000	2200
Teeth	P D																					
11	3.55"	.42	.79	1.14	1.80	2.60	3.36	4.11	4.84	6.28	7.67	9.04	11.7	16.9	23.0	19.6	14.9	11.8	9.69	8.12	6.94	6.01
13	4.18	.51	.95	1.36	2.16	3.11	4.03	4.92	5.80	7.51	9.19	10.8	14.0	20.2	29.1	25.2	19.2	15.2	12.5	10.4	8.91	7.72
15	4.81	.59	1.10	1.59	2.52	3.63	4.70	5.75	6.77	8.77	10.7	12.6	16.4	23.6	34.0	31.2	23.8	18.9	15.4	12.9	11.0	9.57
17	5.44	.68	1.26	1.82	2.88	4.15	5.38	6.58	7.75	10.0	12.3	14.5	18.7	27.0	38.9	37.6	28.7	22.7	18.6	15.6	13.3	11.5
19	6.08	.76	1.43	2.05	3.25	4.68	6.07	7.42	8.74	11.3	13.8	16.3	21.1	30.4	43.8	44.5	33.9	26.9	22.0	18.4	15.7	13.6
21	6.71	.85	1.59	2.29	3.62	5.22	6.76	8.27	9.74	12.6	15.4	18.2	23.6	34.0	48.9	51.7	39.4	31.2	25.6	21.4	18.3	15.9
23	7.34	.94	1.75	2.52	4.00	5.76	7.46	9.12	10.7	13.9	17.0	20.0	26.0	37.4	53.9	59.2	45.1	35.8	29.3	24.6	21.0	18.2
25	7.98	1.03	1.92	2.76	4.38	6.30	8.17	9.98	11.8	15.2	18.6	21.9	28.4	40.9	59.0	64.9	51.1	40.6	33.2	27.8	23.8	20.6
Lubrication •		Type I			Type II						Type III			Type IV								

RATINGS FOR INTERMEDIATE NUMBERS OF TEETH OR RPM MAY BE OBTAINED BY INTERPOLATION

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Table 5 (Continued)

Small Sprocket		HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 100 – 1-1/4" PITCH																		
RPM →		10	20	30	50	75	100	125	150	200	250	300	400	500	600	·900	1000	1200	1400	
Teeth	P D																			
11	4.44"	.81	1.51	2.18	3.45	4.97	6.44	7.88	9.28	12.0	14.7	17.3	22.4	27.4	32.3	27.5	23.4	17.8	14.2	
13	5.22	.97	1.81	2.61	4.13	5.96	7.72	9.43	11.1	14.4	17.6	20.7	26.9	32.8	38.7	35.3	30.1	22.9	18.2	
15	6.01	1.13	2.12	3.05	4.82	6.95	9.00	11.0	13.0	16.8	20.6	24.2	31.4	38.3	45.2	43.7	37.3	28.4	22.5	
17	6.80	1.30	2.42	3.49	5.52	7.96	10.3	12.6	14.9	19.2	23.5	27.7	35.9	43.9	51.7	52.7	45.0	34.3	27.2	
19	7.59	1.46	2.73	3.93	6.23	8.98	11.6	14.2	16.8	21.7	26.5	31.2	40.5	49.5	58.3	62.3	53.2	40.5	32.1	
21	8.39	1.63	3.04	4.38	6.94	10.0	12.9	15.8	18.7	24.2	29.6	34.8	45.1	55.1	64.9	72.4	61.8	47.0	37.3	
23	9.18	1.80	3.36	4.84	7.65	11.0	14.3	17.5	20.6	26.6	32.6	38.4	49.7	60.8	71.7	83.0	70.9	53.9	42.8	
25	9.97	1.97	3.67	5.29	8.37	12.1	15.6	19.1	22.5	29.2	35.7	42.0	54.4	66.5	78.4	94.1	80.3	61.1	48.5	
Lubrication ■		Type I			Type II		Type III						Type IV							

Small Sprocket		HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 120 – 1-1/2" PITCH																		
RPM →		10	20	30	50	75	100	125	150	200	250	300	400	500	600	700	800	900	1000	1200
Teeth	P D																			
11	5.324"	1.37	2.56	3.68	5.82	8.40	10.9	13.3	15.6	20.3	24.8	29.2	37.8	46.3	54.5	46.3	37.9	31.8	27.1	20.6
13	6.268	1.64	3.06	4.41	6.97	10.1	13.0	15.9	18.7	24.3	29.7	35.0	45.3	55.4	65.3	59.5	48.7	40.8	34.9	26.5
15	7.215	1.91	3.57	5.14	8.13	11.7	15.2	18.6	21.9	28.3	34.7	40.8	52.9	64.6	76.1	73.8	60.4	50.6	43.2	32.9
17	8.164	2.19	4.09	5.88	9.31	13.4	17.4	21.3	25.0	32.4	39.7	46.7	60.5	74.0	87.2	89.0	72.8	61.0	52.1	39.6
19	9.114	2.47	4.61	6.64	10.5	15.2	19.6	24.0	28.2	36.5	44.8	52.7	68.2	83.4	98.3	105	86.1	72.1	61.6	46.8
21	10.064	2.75	5.13	7.39	11.7	16.9	21.8	26.7	31.4	40.7	49.8	58.7	76.0	93.0	110	122	100	83.8	71.6	54.4
Lubrication ■		Type I	Type II						Type III				Type IV							

Small Sprocket		HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 140 – 1-3/4" PITCH																
RPM →		10	20	30	50	75	100	125	150	200	250	300	400	500	600	700	800	900
Teeth	P.D.																	
11	6.211"	2.13	3.97	5.72	9.06	13.1	16.9	20.7	24.4	31.5	38.6	45.5	58.9	72.0	65.8	52.4	42.9	35.9
13	7.312	2.55	4.74	6.83	10.9	15.6	20.3	24.7	29.2	37.8	46.2	54.4	70.5	86.2	84.6	67.3	55.1	46.2
15	8.417	2.98	5.56	8.01	12.7	18.3	23.7	28.9	34.1	44.1	54.0	63.6	82.4	101	105	83.4	68.3	57.2
17	9.523	3.41	6.36	9.16	14.5	20.9	27.1	33.1	39.0	50.5	61.7	72.8	94.2	115	126	100	82.4	69.1
19	10.632	3.84	7.17	10.3	16.0	23.5	30.5	37.3	44.0	57.0	70.0	82.1	106	130	149	119	97.4	81.6
21	11.742	4.28	7.98	11.5	18.2	26.2	34.0	41.5	49.0	63.4	77.6	91.4	118	145	171	138	113	94.8
Lubrication ■		Type I		Type II			Type III						Type IV					

Small Sprocket		HP RATINGS – STANDARD SINGLE* STRAND ROLLER CHAIN – NO. 160 – 2" PITCH														
RPM →		10	20	30	50	75	100	125	150	200	250	300	400	500	550	600
Teeth	P.D.															
11	7.099"	3.07	5.74	8.26	13.1	18.8	24.4	29.8	35.1	45.5	55.6	65.5	84.9	96.7	83.9	73.5
13	8.357	3.67	6.85	9.86	15.7	22.5	29.2	35.6	42.0	54.4	66.6	78.4	102	124	108	94.4
15	9.620	4.28	8.00	11.5	18.3	26.3	34.1	41.7	49.0	63.5	77.7	91.5	119	145	134	117
17	10.884	4.90	9.16	13.2	20.9	30.1	39.0	47.7	56.1	72.7	88.9	105	136	166	161	141
19	12.151	5.53	10.3	14.9	23.6	33.9	44.0	53.8	63.2	82.0	100	118	153	188	190	166
21	13.419	6.16	11.5	16.6	26.3	37.8	49.0	59.9	70.5	91.4	112	132	171	209	220	194
Lubrication ■		Type I	Type II		Type III						Type IV					

RATINGS FOR INTERMEDIATE NUMBERS OF TEETH OR RPM MAY BE OBTAINED BY INTERPOLATION

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Assignment Sheet 1

Table 6
Speed Ratio Chart

SPEED RATIOS – CENTER DISTANCES – CHAIN LENGTHS

Teeth on DriveR Sprocket		Teeth on DriveN Sprocket								
		15	16	17	18	19	20	21	22	23
11	Ratio	1.36	1.45	1.55	1.64	1.73	1.82	1.91	2.00	2.09
	CD*	6.469	7.207	7.943	7.669	8.404	8.124	8.857	9.590	9.304
	Length*	26	28	30	30	32	32	34	36	36
12	Ratio	1.25	1.33	1.42	1.50	1.58	1.67	1.75	1.83	1.92
	CD*	7.235	6.971	7.710	8.446	8.174	8.909	8.632	9.365	10.098
	Length*	28	28	30	32	32	34	34	36	38
13	Ratio	1.15	1.23	1.31	1.38	1.46	1.54	1.61	1.69	1.77
	CD*	6.993	7.736	7.473	8.212	8.949	8.679	9.414	9.139	9.872
	Length*	28	30	30	32	34	34	36	36	38
14	Ratio	1.07	1.14	1.21	1.29	1.36	1.43	1.50	1.57	1.64
	CD*	7.748	7.494	8.237	7.975	8.714	9.45	9.183	9.918	9.645
	Length*	30	30	32	32	34	36	36	38	38
15	Ratio	1.00	1.07	1.13	1.20	1.27	1.33	1.40	1.47	1.53
	CD*	7.500	8.249	7.994	8.737	8.477	9.216	9.955	9.686	10.422
	Length*	30	32	32	34	34	36	38	38	40
16	Ratio		1.00	1.06	1.13	1.19	1.25	1.31	1.37	1.44
	CD*		8.000	8.749	8.495	9.238	8.978	9.718	10.457	10.189
	Length*		32	34	34	36	36	38	40	40
17	Ratio			1.00	1.06	1.12	1.18	1.24	1.29	1.35
	CD*			8.500	9.249	8.995	9.739	9.479	10.220	10.959
	Length*			34	36	36	38	38	40	42
18	Ratio				1.00	1.06	1.11	1.17	1.22	1.28
	CD*				9.000	9.749	9.495	10.239	9.980	10.721
	Length*				36	38	38	40	40	42
19	Ratio					1.00	1.05	1.11	1.16	1.21
	CD*					9.500	10.249	9.995	10.740	10.481
	Length*					38	40	40	42	42
20	Ratio						1.00	1.05	1.10	1.15
	CD*						10.000	10.749	10.496	11.240
	Length*						40	42	42	44
21	Ratio							1.00	1.05	1.10
	CD*							10.500	11.249	10.996
	Length*							42	44	44
22	Ratio								1.00	1.05
	CD*								11.000	11.749
	Length*								44	46
23	Ratio									1.00
	CD*									11.500
	Length*									46
24										
25										

*Center Distance (CD) and Chain Length are in PITCHES. To obtain corresponding values in INCHES, multiply by the appropriate Chain Pitch.

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Assignment Sheet 1

Table 6 (Continued)
Speed Ratio Chart

SPEED RATIOS – CENTER DISTANCES – CHAIN LENGTHS

Teeth on DriveR Sprocket		Teeth on DriveN Sprocket							
		24	25	30	32	35	36	40	42
11	Ratio CD* Length*	2.18 10.037 38	2.27 9.744 38	2.72 11.345 44	2.91 12.812 48	3.18 13.976 52	3.27 13.668 52	3.64 15.561 58	3.82 15.983 60
12	Ratio CD* Length*	2.00 9.815 38	2.08 10.547 40	2.50 12.161 46	2.66 12.597 48	2.92 13.761 52	3.00 14.495 54	3.34 15.349 58	3.50 15.773 60
13	Ratio CD* Length*	1.85 10.605 40	1.92 10.324 40	2.31 11.943 46	2.46 12.379 48	2.69 13.546 52	2.77 14.279 54	3.08 15.136 58	3.23 16.605 62
14	Ratio CD* Length*	1.72 10.378 40	1.79 11.112 42	2.14 12.746 48	2.28 13.188 50	2.50 14.361 54	2.57 14.063 54	2.86 15.961 60	3.00 16.391 62
15	Ratio CD* Length*	1.69 10.150 40	1.67 10.884 42	2.00 12.522 48	2.14 12.967 50	2.33 14.141 54	2.40 14.874 56	2.67 15.746 60	2.80 16.177 62
16	Ratio CD* Length*	1.50 10.926 42	1.56 10.654 42	1.88 12.299 48	2.00 13.765 52	2.19 13.921 54	2.25 14.653 56	2.50 15.528 60	2.62 16.994 64
17	Ratio CD* Length*	1.41 10.692 42	1.47 11.429 44	1.76 13.087 50	1.88 13.539 52	2.06 14.721 56	2.12 14.433 56	2.35 16.339 62	2.47 16.777 64
18	Ratio CD* Length*	1.33 11.461 44	1.39 11.195 44	1.67 12.858 50	1.78 13.314 52	1.94 14.497 56	2.00 15.230 58	2.22 16.119 62	2.34 16.557 64
19	Ratio CD* Length*	1.26 11.222 44	1.31 11.963 46	1.58 13.638 52	1.68 14.099 54	1.84 15.288 58	1.89 15.006 58	2.10 16.920 64	2.21 17.364 66
20	Ratio CD* Length*	1.20 10.982 44	1.25 11.723 46	1.50 13.406 52	1.60 13.869 54	1.75 15.061 58	1.80 15.795 60	2.00 16.697 64	2.10 17.142 66
21	Ratio CD* Length*	1.14 11.741 46	1.19 11.483 46	1.43 13.172 52	1.52 14.646 56	1.67 14.833 58	1.71 15.567 60	1.90 16.473 64	2.00 17.939 68
22	Ratio CD* Length*	1.09 11.496 46	1.14 12.241 48	1.36 13.942 54	1.45 14.413 56	1.59 15.613 60	1.64 15.338 60	1.82 17.262 66	1.91 17.714 68
23	Ratio CD* Length*	1.04 12.249 48	1.09 11.996 48	1.30 13.705 54	1.39 14.178 56	1.52 15.382 60	1.56 16.117 62	1.74 17.035 66	1.83 17.489 68
24	Ratio CD* Length*	1.00 [illegible] 48	1.04 12.750 50	1.25 14.404 56	1.33 14.946 58	1.46 [illegible] [illegible]	1.50 15.886 62	1.67 17.818 68	1.75 18.275 70
25	Ratio CD* Length*		1.00 12.500 50	1.20 14.228 56	1.28 14.708 58	1.40 15.921 62	1.44 16.658 64	1.60 17.588 68	1.68 18.047 70

SPEED RATIOS – CENTER DISTANCES – CHAIN LENGTHS

Teeth on DriveR Sprocket		Teeth on DriveN Sprocket									
		45	48	54	60	70	72	80	84	96	112
11	Ratio CD* Length*	4.09 17.139 64	4.36 18.294 68	4.91 19.539 74	5.45 21.843 82			*Center Distance (CD) and Chain Length are in PITCHES. To obtain corresponding values in INCHES multiply by the appropriate Chain Pitch			
12	Ratio CD* Length*	3.75 16.930 64	4.00 18.085 68	4.50 20.396 76	5.00 21.637 82	5.83 25.834 96	6.00 26.244 98				
13	Ratio CD* Length*	3.46 16.719 64	3.69 18.925 70	4.15 20.186 76	4.61 22.496 84	5.39 25.628 96	5.54 26.038 98				
14	Ratio CD* Length*	3.22 17.553 66	3.43 18.713 70	3.86 19.977 76	4.29 22.287 84	5.00 25.422 96	5.14 25.834 98	5.71 28.545 108	6.00 30.439 114		
15	Ratio CD* Length*	3.00 17.340 66	3.20 18.500 70	3.60 20.819 78	4.00 22.079 84	4.67 26.279 98	4.80 26.694 100	5.33 29.413 110	5.60 30.234 114		
16	Ratio CD* Length*	2.81 18.161 68	3.00 18.287 70	3.38 20.607 78	3.75 22.923 86	4.37 26.071 98	4.50 26.487 100	5.00 29.206 110	5.25 31.098 116	6.00 34.633 130	
17	Ratio CD* Length*	2.65 17.945 68	2.82 19.110 72	3.18 20.395 78	3.53 22.712 86	4.12 25.863 98	4.24 27.337 102	4.70 29.000 110	4.94 30.891 116	5.64 34.429 130	
18	Ratio CD* Length*	2.50 17.728 68	2.67 18.894 72	3.00 21.223 80	3.33 22.501 86	3.89 26.708 100	4.00 27.128 102	4.44 29.855 112	4.66 30.685 116	5.33 35.295 132	
19	Ratio CD* Length*	2.37 18.536 70	2.52 18.677 72	2.84 21.008 80	3.16 23.332 88	3.68 26.498 100	3.79 26.918 102	4.21 29.647 112	4.41 31.539 118	5.05 35.088 132	5.90 40.516 152
20	Ratio CD* Length*	2.25 18.317 70	2.40 19.489 74	2.70 21.827 82	3.00 23.119 88	3.50 26.287 100	3.60 27.758 104	4.00 30.493 114	4.20 31.330 118	4.80 34.882 132	5.60 40.312 152
21	Ratio CD* Length*	2.14 18.096 70	2.28 19.270 74	2.57 21.609 82	2.86 23.492 90	3.33 27.121 102	3.43 27.547 104	3.81 30.283 114	4.00 31.122 118	4.57 35.738 134	5.33 41.177 154
22	Ratio CD* Length*	2.04 18.895 72	2.18 20.073 76	2.46 21.392 82	2.73 23.726 90	3.18 26.910 102	3.27 27.334 104	3.64 30.073 114	3.82 31.965 120	4.36 35.531 134	5.03 40.971 154
23	Ratio CD* Length*	1.96 18.671 72	2.08 18.829 74	2.34 22.200 84	2.61 23.510 90	3.04 26.695 102	3.13 28.164 106	3.48 30.910 116	3.65 31.755 120	4.17 35.322 134	4.87 40.765 154
24	Ratio CD* Length*	1.88 19.463 74	2.00 19.628 76	2.25 21.980 84	2.50 24.321 92	2.92 27.522 104	3.00 27.954 106	3.33 30.699 118	3.50 31.544 120	4.00 36.170 136	4.67 41.622 156
25	Ratio CD* Length*	1.80 19.237 74	1.92 20.422 78	2.16 21.760 84	2.40 24.104 92	2.80 27.306 104	2.88 27.736 106	3.20 30.486 116	3.36 32.380 122	3.84 35.960 136	4.48 41.414 156

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Power Transmission: Belts, Chains, and Fluid Power
Unit 10

Assignment Sheet 2—Select V-Belts For Given Applications

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Correct data for Problem A	______
Correct data for Problem B	______

Directions: Using the charts and tables that accompany this assignment sheet, select conventional V-belts for selected applications. Follow procedures in the example that follows:

Example problem: An application requires a 30 HP 1750RPM squirrel cage normal torque electric motor to drive a reciprocating pump at 479 RPM. The approximate shaft center distance is 30″. The motor has a 1⅞″ shaft and the pump shaft is 2¼″. Both shafts have standard key seats. Service is 18 hours per day. How many conventional V-belts are needed? What type V-belts should be selected?

Example solution:

Step 1: Use the following procedure to find the design horsepower. Determine the service factor from table 1. Look under the normal column for normal torque AC motors, and see note 6 for continuous service. Look down the DRIVEN MACHINE column for Pumps (Piston). The service factor is 1.4. Multiply the service factor by the HP design rating of 30. 30 (HP rating) × 1.4 (service factor) = 42 HP.

Step 2: Use the following procedure to choose the belt cross section. Refer to table 2. Find 42 on the horizontal line at the bottom of the chart and follow up the chart vertically until extension of the 42 point intersects the extension of the "RPM of the faster shaft" (1750 RPM) on the left of the table. The belt cross section required is BX (Assume a Torque Flex). Now, go to table 3 to find the recommended sheave diameter. This table indicates that for a 30 HP, 1750 RPM motor, the minimum recommended sheave diameter is 5 1/4″ or 5.25″.

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Assignment Sheet 2

Step 3: Use the following procedure to select the drive. Go to the Conventional V-Belt Drive Selection Table 4. Find the 1750 RPM column, and then just to the left, go down the Drive Speed column until you find the RPM closest to the 479 RPM of the motor. 480 RPM is the speed closest to 479 RPM, so use the 480 RPM as reference. Now, move to the right until you note that the HP per belt is 13.46 HP for the torque flex belt. Next, go to the columns to the left of the page and find the motor sheave diameter. The driver has a diameter of 6.6″. The pump sheave diameter is 25.0″. Stay on the same line to move across and locate the center distance closest to the desired distance of 30″. The closest center distance is 30.7″. Now read up the column to determine the type of belt required. It is a B112, meaning a BX112 Torque Flex belt.

Step 4: Use the following procedure to determine the number of belts required. Apply the arc length correction factor and multiply it by the belt horsepower of 13.46, established in Step 3. The arc-length correction factor is the closest bold-faced figure five preceeding lines below the center distance of 30.7. In this case, the correction factor is .98. Since 13.46 × .98 = 13.19 or 13.2, and the 13.2 is the corrected horsepower per belt. Now, to get the number of belts needed, divide 42 (design horsepower) by 13.2 (corrected horsepower per belt). Thus, 42 divided by 13.2 = 3.28. Since 3.28 is greater than 3, move on to the next highest number, and that means 4 belts are required.

The selection process indicates 4 conventional BX112 Torque Flex belts are required for the job. Note also that the selection process provides both the motor and pump sheave sizes. The motor sheave has a 6.6″ diameter and the pump sheave has a 25″ diameter.

CAD Alert: Use a CAD system to draw two points representing the center-to-center distance. Use the sheave diameters to construct two circles at the points. Construct tangent lines to represent belts. Trim the circles and have the CAD system compute the perimeter of the lines and arcs. Compare the answer to your calculations.

Problems:

A: An application requires a 10 HP, 1160 RPM AC high torque electric motor to operate a laundry machine at 351 RPM for 4 hours a day. The distance between centers is 42″ to 50″. A belt with long service life is desired. The motor has a 1.875″ shaft, and the laundry machinery has a 2.25″ shaft. Torque Flex belts are specified. How many belts will be required?

B: An application requires a 25 HP, 1750 RPM AC normal torque split-phase motor to operate a pulverizer at 500 RPM for 17 hours a day. The distance between centers is 29″ to 30″. The motor has a 1.5″ shaft, and the pulverizers has a 2″ shaft. Sure Grip premium belts are specified. How many belts will be required?

Assignment Sheet 2

Table 1

SERVICE FACTORS

DRIVEN MACHINE See Note 1	DRIVER					
	AC Normal Torque Electric Motor (NEMA Design A-B) See Note 2			AC High Torque Electric Motor (NEMA Design C-D) See Note 3		
	Intermittent Service See Note 4	Normal Service See Note 5	Continuous Service See Note 6	Intermittent Service See Note 4	Normal Service See Note 5	Continuous Service See Note 6
Agitators for Liquids Blowers and Exhausters Centrifugal Pumps and Compressors Conveyors (Light Duty) Fans (up to 10 H.P.)	1.0	1.1	1.2	1.1	1.2	1.3
Belt Conveyors for Sand, Grain, etc Fans (over 10 H.P.) Generators Laundry Machinery Line Shafts Machine Tools Mixers (Dough) Positive Displacement Rotary Pumps Printing Machinery Punches-Presses-Shears See Note 1 Revolving and Vibrating Screens	1.1	1.2	1.3	1.2	1.3	1.4
Blowers (Positive Displacement) Brick Machinery Compressors (Piston) See Note 1 Conveyors (Drag-Pan-Screw) Elevators (Bucket) Exciters Hammer Mills Paper Mill Beaters Pulverizers Pumps (Piston) Saw Mill and Woodworking Machinery Textile Machinery	1.2	1.3	1.4	1.4	1.5	1.6
Crushers (Giratory-Jaw-Roll) See Note 1 Mills (Ball-Rod-Tube) See Note 1 Hoists See Note 1 Rubber Calenders-Extruders-Mills See Note 1	1.3	1.4	1.5	1.5	1.6	1.8

Note 1 The Driven Machines listed above are representative samples only. When one of the sheaves of the drive is used as a flywheel to reduce speed fluctuations and equalize the energy exerted at the shaft or for applications involving impact or jam loads specially constructed sheaves may be required. Consult the manufacturer.

Note 2 Included under this heading are the following electric motors: Synchronous and Squirrel Cage AC Normal Torque, AC Split Phase, DC Shunt Wound and Internal Combustion Engines.

Note 3 Included under this heading are the following electric motors: AC High Torque, AC Hi-Slip, AC Repulsion Induction, AC Single Phase Series Wound, AC Slip Ring and DC Compound Wound.

Note 4 Intermittent Service refers to 3—5 hours of daily or seasonal operation.

Note 5 Normal Service indicates 8—10 hours of daily operation.

Note 6 Continuous Service refers to 16—24 hours of daily operation.

Note 7 If idlers are used, add the following to the service factor:

Idler on slack side (inside)	**None**
Idler on slack side (outside)	0.1
Idler on tight side (inside)	0.1
Idler on tight side (outside)	0.2

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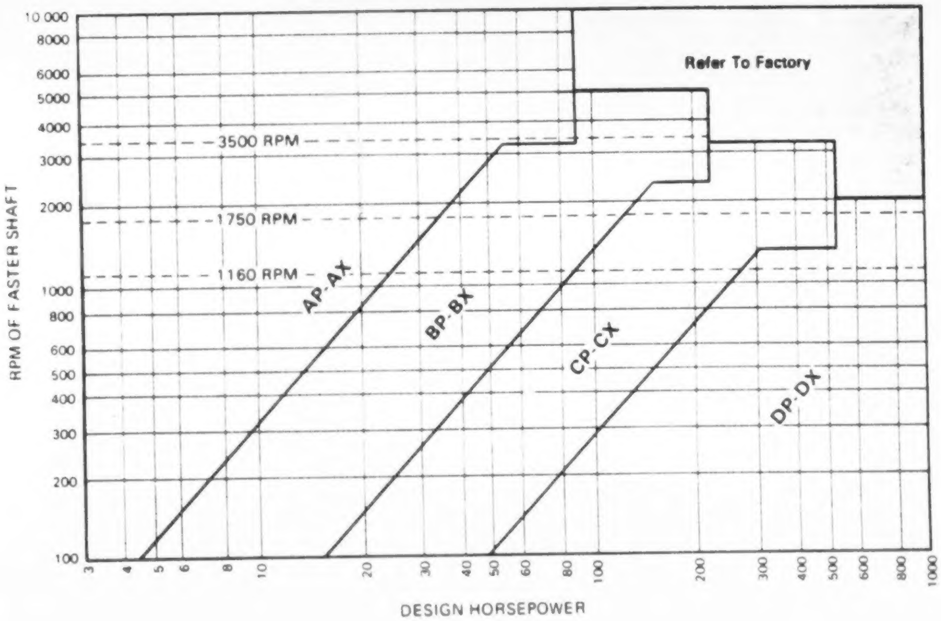
Assignment Sheet 2

Table 2

Belt Cross Section Selection Chart



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Assignment Sheet 2

Table 3

MINIMUM RECOMMENDED SHEAVE DIAMETERS IN INCHES FOR ELECTRIC MOTORS

Motor Horse-Power	MOTOR RPM					
	575	695	870	1160	1750	3450
½	...	...	2¼	...	...	...
¾	...	...	2½	2¼	...	...
1	3	2½	2½	2½	2¼	...
1½	3	3	3	2½	2½	2¼
2	3¾	3	3	2½	2½	2½
3	4½	3¾	3	3	2½	2½
5	4½	4½	3¾	3	3	2½
7½	5¼	4½	4½	3¾	3	3
10	6	5¼	4½	4½	3¾	3
15	6¾	6	5¼	4½	4½	3¾
20	8¼	6¾	6	5¼	4½	4½
25	9	8¼	6¾	6	4½	4½
30	10	9	6¾	6¾	5¼	...
40	**10**	10	8¼	6¾	6	...
50	**11**	**10**	9	8¼	6¾	...
60	**12**	**11**	10	9	7½	...
75	**14**	**13**	**10**	10	9	...
100	**18**	**15**	**13**	**13**	10	...
125	**20**	**18**	**15**	**13**	11	...
150	**22**	**20**	**18**	**13**	...	...
200	**22**	**22**	**22**	...	...	...
250	**22**	**22**	...	...	...	...
300	**27**	**27**	...	...	...	...

NOTE: Data in the clear section is from National Electrical Manufacturers Association Standard MGI-14-45. Data in the shaded section is a composite of Electrical Motor Manufacturers. They are generally conservative, and specific motors and bearings may permit the use of a smaller motor sheave. Consult the motor manufacturer.

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Assignment Sheet 2

Table 4

CONVENTIONAL V-BELTDRIVE SELECTION TABLES

RATIO	STOCK SHEAVES			DRIVEN SPEEDS AND HORSEPOWER RATINGS PER BELT										CENTER DISTANCE AND COMBINED ARC-LENGTH CORRECTION FACTOR ▲																			
				1160 RPM			1750 RPM			3500 RPM																							
	Datum Diameter		Number Grooves ◆	Driven Speed	H P Ratings		Driven Speed	H P Ratings		Driven Speed	H P Ratings		B60	B68	B75	B81	B85	B90	B97	B105	B112	B120	B128	B144	B158	B173	B180	B195	B210	B240	B270	B300	B360
	DR	DN			Sure-Grip Premium	Torque-Flex		Sure-Grip Premium	Torque-Flex		Sure-Grip Premium	Torque-Flex																					
3.26	5.4	18.4	1-8,10	356	5.59	7.39	537	7.48	10.26	1075	10.11	15.94		14.8	18.5	21.7	23.8	26.4	30.0	34.1	37.6	41.7	45.7	53.8	60.8	68.4	71.9	79.4	87.0	101.2	116.3	131.3	161.3
3.27	7.4	25.0	2-8,10	355	8.38	11.21	535	11.12	15.48									18.4	22.2	26.5	30.1	34.3	38.4	46.6	53.7	61.3	64.8	72.4	79.9	94.3	109.3	124.4	154.4
3.30	4.6	16.0	1-6	352	4.42	5.80	531	5.88	8.04	1061	8.12	12.65	13.5	17.8	21.4	24.5	26.6	29.1	32.7	36.8	40.3	44.3	48.4	56.4	63.5	71.0	74.5	82.0	89.5	103.8	118.8	133.8	163.9
3.31	5.8	20.0	1-8,10	351	6.17	8.17	529	8.24	11.35	1059	10.93	17.43			16.6	19.8	22.0	24.6	28.2	32.3	35.9	40.0	44.0	52.1	59.2	66.7	70.3	77.8	85.3	99.6	114.7	129.7	159.7
3.31	4.4	15.4	1-6	350	4.12	5.40	529	5.47	7.47	1057	7.56	11.77	14.3	18.5	22.1	25.2	27.3	29.8	33.4	37.4	41.0	45.0	49.0	57.1	64.1	71.6	75.1	82.7	90.2	104.4	119.5	134.5	164.5
													0.80 ■	■ 0.84	0.8[illegible]	0.90	0.91	0.91	0.94	0.97	0.99	1.01	1.03	1.07	1.09	1.11	1.12	1.14	1.16	1.19	1.22	1.25	1.29■
3.36	3.8	13.6	1-6	346	3.20	4.18	521	4.20	5.74	1043	5.73	8.98	16.5	20.8	24.2	27.3	29.3	31.8	35.4	39.4	42.9	47.0	51.0	59.0	66.0	73.6	77.1	84.6	92.1	106.4	121.4	136.4	166.4
3.37	5.2	18.4	1-6	344	5.30	7.00	519	7.08	9.71	1037	9.65	15.16		14.9	18.7	21.8	23.9	26.5	30.1	34.2	37.8	41.8	45.9	53.9	61.0	68.5	72.0	79.6	87.1	101.4	116.4	131.4	161.5
3.38	8.6	30.0	2-8,10	342	9.95	13.40	516	13.05	18.36												24.3	28.6	32.8	41.1	48.3	56.0	59.6	67.2	74.8	89.2	104.3	119.3	149.4
3.38	3.4	12.4	1-6	342	2.58	3.35	516	3.34	4.56	1031	4.40	7.01	17.9	22.0	25.6	28.6	30.6	33.2	36.7	40.7	44.2	48.3	52.3	60.3	67.3	74.8	78.4	85.9	93.4	107.6	122.7	137.7	167.7
3.42	5.6	20.0	1-8,10	340	5.88	7.78	512	7.86	10.81	1025	10.53	16.70			16.8	20.0	22.1	24.7	28.3	32.5	36.0	40.1	44.2	52.3	59.3	66.9	70.4	77.9	85.5	99.8	114.8	129.8	159.9
													0.85 ■	■ 0.86	0.88	0.91	0.92	0.94	0.96	0.99	0.98	1.01	1.03	1.06	1.09	1.11	1.12	1.14	1.16	1.19	1.22	1.25	1.29■
3.44	4.4	16.0	1-6	338	4.12	5.40	509	5.47	7.47	1018	7.56	11.77	13.7	17.9	21.6	24.7	26.7	29.3	32.8	36.9	40.4	44.5	48.5	56.6	63.6	71.1	74.6	82.2	89.7	104.0	119.0	134.0	164.0
3.45	7.0	25.0	2-8,10	337	7.84	10.46	508	10.43	14.48									18.7	22.5	26.7	30.4	34.5	38.7	46.9	54.0	61.6	65.1	72.7	80.2	94.6	109.6	124.7	154.7
3.46	4.2	15.4	1-6	336	3.82	5.00	506	5.05	6.90	1013	6.98	10.86	14.4	18.6	22.3	25.4	27.4	30.0	33.5	37.6	41.1	45.1	49.2	57.2	64.2	71.8	75.3	82.8	90.3	104.6	119.6	134.6	164.7
3.50	5.0	18.4	1-6	331	5.01	6.60	500	6.69	9.16	1000	9.17	14.35		15.1	18.8	22.0	24.1	26.6	30.2	34.3	37.9	42.0	46.0	54.1	61.1	68.7	72.2	79.7	87.3	101.5	116.6	131.6	161.6
3.53	3.6	13.6	1-6	329	2.90	3.77	498	3.77	5.16	993	5.08	8.01	16.6	20.8	24.4	27.4	29.4	32.0	35.5	39.6	43.1	47.1	51.1	59.2	66.2	73.7	77.2	84.7	92.3	106.5	121.5	136.5	166.6
													0.81 ■	■ 0.85	0.89	0.91	0.93	0.92	0.95	0.98	1.00	1.02	1.04	1.07	1.08	1.12	1.13	1.15	1.16	1.20	1.23	1.25	1.29■
3.53	5.4	20.0	1-8,10	328	5.59	7.39	495	7.48	10.26	990	10.11	15.95			16.9	20.1	22.2	24.8	28.5	32.6	36.2	40.3	44.3	52.4	59.5	67.0	70.6	78.1	85.6	99.9	115.0	130.0	160.0
3.54	6.8	25.0	2-8,10	328	7.57	10.08	494	10.08	13.97									18.8	22.6	26.8	30.5	34.7	38.8	47.0	54.1	61.7	65.3	72.8	80.4	94.7	109.8	124.8	154.9
3.58	4.2	16.0	1-6	323	3.82	5.00	488	5.05	6.90	976	6.98	10.86	13.8	18.0	21.7	24.8	26.9	29.4	33.0	37.0	40.6	44.6	48.7	56.7	63.7	71.3	74.8	82.3	89.8	104.1	119.1	134.2	164.2
3.61	4.0	15.4	1-6	321	3.51	4.59	484	4.63	6.32	968	6.37	9.94	14.5	18.8	22.4	25.5	27.5	30.1	33.7	37.7	41.2	45.3	49.3	57.4	64.4	71.9	75.4	83.0	90.5	104.8	119.8	134.8	164.8
3.63	8.0	30.0	2-8,10	319	9.18	12.32	482	12.11	16.95											20.8	24.6	28.9	33.2	41.5	48.8	56.4	60.0	67.6	75.2	89.6	104.7	119.8	149.9
													0.80 ■	■ 0.85	0.87	0.90	0.91	0.91	0.94	0.94	0.97	1.00	1.02	1.05	1.08	1.11	1.12	1.14	1.16	1.19	1.22	1.25	1.29■
3.64	4.8	18.4	1-6	319	4.71	6.20	481	6.29	8.60	963	8.66	13.52		15.2	18.9	22.1	24.2	26.8	30.4	34.5	38.0	42.1	46.1	54.2	61.3	68.8	72.3	79.9	87.4	101.7	116.7	131.7	161.8
3.64	6.8	25.0	2-8,10	318	7.29	9.71	480	9.73	13.46	961	12.23	20.08						18.9	22.7	27.0	30.7	34.8	38.9	47.1	54.3	61.9	65.4	73.0	80.5	94.9	109.9	125.0	155.0
3.66	5.2	20.0	1-6	317	5.30	7.00	478	7.09	9.72	956	9.65	15.16			17.0	20.2	22.4	25.0	28.6	32.7	36.3	40.4	44.5	52.6	59.6	67.2	70.7	78.2	85.8	100.1	115.1	130.1	160.2
3.71	3.4	13.6	1-6	312	2.58	3.35	471	3.34	4.57	943	4.40	7.02	16.7	20.9	24.5	27.5	29.6	32.1	35.7	39.7	43.2	47.3	51.3	59.3	66.3	73.9	77.4	84.9	92.4	106.7	121.7	136.7	166.7
3.75	6.4	25.0	2-8,10	309	7.01	9.33	466	9.36	12.94	933	11.95	19.46						19.0	22.8	27.1	30.8	35.0	39.1	47.3	54.4	62.0	65.5	73.1	80.7	95.0	110.1	125.1	155.2
													0.84 ■	■ 0.84	0.86	0.89	0.91	0.89	0.93	0.96	0.98	1.00	1.02	1.05	1.08	1.11	1.12	1.14	1.16	1.19	1.22	1.25	1.29■
3.75	4.0	16.0	1-6	309	3.51	4.59	466	4.63	6.33	933	6.37	9.94	13.9	18.2	21.8	24.9	27.0	29.6	33.1	37.2	40.7	44.8	48.8	56.9	63.9	71.4	74.9	82.5	90.0	104.3	119.3	134.3	164.3
3.78	4.6	18.4	1-6	307	4.42	5.80	463	5.88	8.04	925	8.13	12.66		15.3	19.1	22.2	24.3	26.9	30.5	34.6	38.2	42.2	46.3	54.4	61.4	69.0	72.5	80.0	87.5	101.8	116.9	131.9	161.9
3.79	3.8	15.4	1-6	306	3.21	4.18	462	4.21	5.74	924	5.74	8.98	14.7	18.9	22.5	25.6	27.7	30.2	33.8	37.8	41.4	45.4	49.5	57.5	64.5	72.1	75.6	83.1	90.6	104.9	119.9	134.9	165.0
3.80	5.0	20.0	1-6	305	5.01	6.60	461	6.69	9.16	921	9.17	14.35			17.1	20.4	22.5	25.1	28.7	32.9	36.5	40.5	44.6	52.7	59.8	67.3	70.8	78.4	85.9	100.2	115.3	130.3	160.3
3.87	6.2	25.0	2-8,10	300	6.73	8.94	453	9.00	12.41	905	11.65	18.82						19.2	23.0	27.2	30.9	35.1	39.2	47.4	54.5	62.1	65.7	73.3	80.8	95.2	110.2	125.3	155.3
													0.80 ■	■ 0.84	0.86	0.89	0.91	0.91	0.94	0.97	0.99	1.01	1.03	1.06	1.09	1.11	1.12	1.14	1.16	1.19	1.22	1.25	1.29■
3.91	7.4	30.0	2-8,10	298	8.38	11.21	447	11.12	15.48											21.1	25.0	29.3	33.6	41.9	49.2	56.8	60.4	68.0	75.6	90.0	105.1	120.2	150.3
3.93	9.4	38.0	2-8,10	295	10.98	14.83	445	14.21	20.18															32.6	40.1	48.0	51.6	59.4	67.1	81.6	96.8	112.0	142.2
3.93	3.8	16.0	1-6	295	3.21	4.18	445	4.21	5.74	890	5.74	8.99	14.0	18.3	22.0	25.1	27.1	29.7	33.3	37.3	40.9	44.9	48.9	57.0	64.0	71.6	75.1	82.6	90.1	104.4	119.4	134.5	164.5
3.94	4.4	18.4	1-6	294	4.12	5.40	444	5.47	7.48	888	7.57	11.78		15.4	19.2	22.4	24.5	27.0	30.7	34.7	38.3	42.4	46.4	54.5	61.6	69.1	72.6	80.2	87.7	102.0	117.0	132.1	162.1
3.95	4.8	20.0	1-6	294	4.72	6.20	444	6.29	8.61	887	8.66	13.52			17.3	20.5	22.6	25.2	28.9	33.0	36.6	40.7	44.7	52.8	59.9	67.5	71.0	78.5	86.1	100.4	115.4	130.4	160.5
													0.79 ■	■ 0.82	0.85	0.89	0.90	0.92	0.95	0.94	0.97	0.99	1.02	1.03	1.06	1.08	1.10	1.13	1.15	1.18	1.21	1.24	1.29■
3.98	3.6	15.4	1-6	291	2.90	3.77	440	3.78	5.16	879	5.08	8.01	14.8	19.0	22.7	25.8	27.8	30.4	33.9	38.0	41.5	45.6	49.6	57.7	64.7	72.2	75.7	83.3	90.8	105.1	120.1	135.1	165.1
3.98	6.0	25.0	2-8,10	291	6.45	8.56	439	8.63	11.88	878	11.31	18.14						19.3	23.1	27.4	31.1	35.2	39.4	47.6	54.7	62.3	65.8	73.4	81.0	95.3	110.4	125.4	155.5
4.10	4.8	20.0	1-6	283	4.42	5.80	426	5.88	8.04	853	8.13	12.66			17.4	20.6	22.7	25.4	29.0	33.1	36.7	40.8	44.9	53.0	60.1	67.6	71.1	78.7	86.2	100.5	115.6	130.6	160.6
4.11	4.2	18.4	1-6	282	3.82	5.00	425	5.05	6.90	851	6.98	10.87		15.6	19.3	22.5	24.6	27.2	30.8	34.9	38.5	42.5	46.6	54.7	61.7	69.3	72.8	80.3	87.8	102.1	117.2	132.2	162.2
4.12	5.8	25.0	2-8,10	282	6.17	8.17	425	8.25	11.35	850	10.94	17.44						19.4	23.2	27.5	31.2	35.4	39.5	47.7	54.8	62.4	66.0	73.5	81.1	95.4	110.5	125.6	155.6
													0.80 ■	■ 0.83	0.85	0.89	0.91	0.89	0.92	0.95	0.98	1.00	1.02	1.06	1.08	1.11	1.12	1.14	1.16	1.19	1.22	1.25	1.29■
4.13	7.0	30.0	2-8,10	281	7.84	10.47	424	10.44	14.48											21.4	25.3	29.6	33.8	42.2	49.4	57.1	60.7	68.3	75.9	90.3	105.4	120.5	150.6
4.13	3.8	16.0	1-6	281	2.90	3.77	424	3.78	5.16	847	5.08	8.01	14.2	18.4	22.1	25.2	27.3	29.8	33.4	37.5	41.0	45.1	49.1	57.1	64.2	71.7	75.2	82.8	90.3	104.6	119.6	134.6	164.6
4.19	3.4	15.4	1-6	277	2.59	3.36	418	3.34	4.57	835	4.40	7.02	14.9	19.2	22.8	25.9	28.0	30.5	34.1	38.1	41.7	45.7	49.8	57.8	64.8	72.4	75.9	83.4	90.9	105.2	120.2	135.2	165.3
4.24	6.8	30.0	2-8,10	274	7.57	10.09	413	10.08	13.97											21.5	25.4	29.7	34.0	42.3	49.6	57.3	60.8	68.5	76.1	90.5	105.6	120.7	150.8
4.26	5.6	25.0	2-8,10	273	5.88	7.78	411	7.87	10.81	823	10.54	16.71						19.5	23.4	27.6	31.3	35.5	39.6	47.8	55.0	62.6	66.1	73.7	81.3	95.6	110.7	125.7	155.8
													0.79 ■	■ 0.85	0.89	0.91	0.93	0.90	0.94	0.91	0.95	0.98	1.00	1.04	1.07	1.10	1.11	1.13	1.15	1.18	1.22	1.24	1.29■
4.28	4.4	20.0	1-6	271	4.12	5.40	409	5.47	7.48	818	7.57	11.78			17.5	20.8	22.9	25.5	29.1	33.3	36.9	41.0	45.0	53.1	60.2	67.8	71.3	78.8	86.4	100.7	115.7	130.7	160.8
4.29	8.6	38.0	2-8,10	271	9.95	13.41	409	13.05	18.37															33.1	40.6	48.5	52.2	59.9	67.6	82.2	97.4	112.5	142.7
4.30	4.0	18.4	1-6	270	3.51	4.59	407	4.63	6.33	813	6.37	9.94		15.7	19.5	22.6	24.7	27.3	30.9	35.0	38.6	42.7	46.7	54.8	61.9	69.4	72.9	80.5	88.0	102.3	117.3	132.4	162.4
4.35	3.4	16.0	1-6	267	2.59	3.36	402	3.34	4.57	804	4.41	7.02	14.3	18.6	22.2	25.3	27.4	30.0	33.5	37.6	41.2	45.2	49.2	57.3	64.3	71.9	75.4	82.9	90.4	104.7	119.7	134.8	164.8
4.36	8.0	30.0	2-8,10	266	7.29	9.71	401	9.73	13.46	802	12.23	20.08								21.6	25.5	29.8	34.1	42.5	49.7	57.4	61.0	68.8	76.2	90.6	105.7	120.8	150.9
													0.78 ■	■ 0.82	0.85	0.88	0.90	0.92	0.95	0.94	0.97	0.99	1.01	1.03	1.06	1.09	1.10	1.13	1.15	1.18	1.21	1.24	1.29■

◆ Sheaves stocked with grooves shown. Other size sheaves and constructions available on a made-to-order basis.
For Sure-Grip Bushing information see Section 1M and page 20M—98 for balancing standards.

▲ Not all available belt lengths are shown. Refer to page 88 for complete listing.
■ Combined Arc-Length correction factors for 5 preceding lines.

Courtesy T. B. Wood's Sons Company

Power Transmission:
Gears, Bearings, and Cams
Unit 11

Objective Sheet

Unit Objective

After completing this unit, the student should be able to construct spur, bevel, and worm gear, and calculate gear ratios and gear speeds. The student should also be able to draw a cam and select bearings from supply sources. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to power transmission with their correct definitions.
2. Match types of gears to their relation of axes positions.
3. Identify parts of gear teeth.
4. Identify parts of pinion and gear.
5. List cutting data needed for spur gear drawings.
6. Identify parts of a bevel gear.
7. Complete a list of cutting data needed for bevel gears.
8. List cutting data needed for worm.
9. Complete a list of cutting data needed for worm wheel gear.
10. Calculate gear ratios.
11. Determine gear rotation.

Objective Sheet

12. Calculate gear speed.
13. List types of couplings.
14. Differentiate between types of bearings.
15. Identify cam nomenclature.
16. Identify types of cam followers.
17. Select types of cam motions.
18. Construct a spur gear drawing. (Assignment Sheet 1)
19. Construct a bevel gear. (Assignment Sheet 2)
20. construct a worm and worm gear. (Assignment Sheet 3)
21. Calculate gear ratios. (Assignment Sheet 4)
22. Determine gear rotation. (Assignment Sheet 5)
23. Calculate gear speeds. (Assignment Sheet 6)
24. Construct a cam drawing. (Assignment Sheet 7)
25. Select types of bearings from handbooks. (Assignment Sheet 8)

Power Transmission: Gears, Bearings, and Cams
Unit 11

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for enrichment of exceptional students as well as accommodation of special needs students.
4. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.
5. Develop teaching plan. Adjust for different learning styles.
6. Make copies of Unit Evaluation Form.

Delivery and Application

7. Provide students with unit of instruction.
8. Discuss unit and specific objectives.
9. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.
10. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Evaluation

11. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
12. Make copies of the written test. Add or modify test questions as needed.
13. Give written test.
14. Compile assignment sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignments.
15. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Check industries in your area for firms that use equipment powered by gears, bearing, and cams. Arrange for students to visit these facilities and note and report on the types of equipment they see. Skill areas: **Foundation skills, writing, and listening**.
2. Have samples of different types of gears to show as students study Objective 2. Relate gear design to power transmission. Skill areas: **Foundation skills, reading**.
3. Have good gear examples to show students as they study cutting data presented in Objectives 5 and 7. Skll areas: **Learning skills, learning to learn**.
4. Prepare examples of the gear ratios, gear rotation, and gear speed as they are presented in Objectives 10, 11, and 12. Divide class into teams and have them select one of the three areas covered and prepare a good demonstration of it for the rest of the class. Skill areas: **Group effectiveness skills, teamwork**.

Resources Used in Developing This Unit

1. Giesecke, Frederick E. *Technical Drawing.* New York: Macmillan Publishing Company, 1992.
2. Jensen, Cecil, and Jay Helsel. *Engineering Drawing and Design.* New York: Gregg Division/McGraw-Hill Book Company, 1979.
3. *Gear Drawing Standards: Part 1, for Spur, Helical, Double Helical, and Rack.* ANSI Y14.7.1-197 (R1988). New York: American National Standards Institute, 1988.
4. *Gear and Spline Drawing Standards: Part 2, Bevel and Hypoid Gears.* ANSI Y14.7.2-1978 (R1989). New York: American National Standards Institute, 1989.
5. *Fundamentals of Service, Power Trains Compact Equipment.* Moline, IL: Deere & Company, 1993.
6. *Gear Nomenclature, Definitions of Terms with Symbols.* ANSI/AGMA 1012-F90. New York: American National Standards Institute, 1990.
7. *Basic Gear Geometry.* ANSI/AGMA 115-01 1989. New York: American National Standards Institute, 1989.
8. *Design Manual for Bevel Gearing.* ANSI/AGMA 2005-B88. New York: American National Standards Institute, 1988.

Power Transmission: Gears, Bearings, and Cams
Unit 11

Answers to Assignment Sheets

Assignment Sheet 1

A. Drawing evaluated to the satisfaction of the instructor
Chordal addendum = .575
B. Drawing evaluated to the satisfactio nof the instructor
Pitch diameter = 12
Whole depth = .2697
Chordal addendum = .2008

Assignment Sheet 2

A. Drawing evaluated to the satisfaction of the instructor
B.

CUTTING DATA		
	Gear	Pinion
Number of Teeth	30	20
Diametral Pitch	5	
Pressure Angle	14½°	
Whole Depth	43.14	
Root Angle	52.6°	30.4°
Face Angle	59.5°	36.9°
Chordal Thickness	3.14	.314
Addendum	.2	

Assignment Sheet 3

A. Drawing evaluated to the satisfaction of the instructor
Whole depth = .343
Face length = 2.61
B. Drawing evaluated to the satisfaction of the instructor
Throat diameter = 6.048
Pitch diameter = 5.730
Rim radius = 1.650 R

Answers to Assignment Sheets

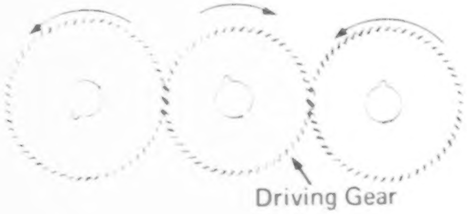
Assignment Sheet 4

A. 1. .25:1
2. .75:1
3. 3:1
4. 5:1

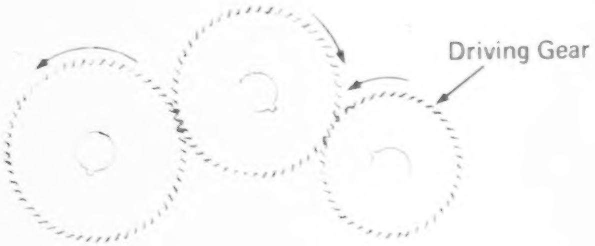
B. 1. .55:1
2. 1.82:1
3. 4:11:1
4. 5.70:1
5. 5.11:1
6. 5.09:1

Assignment Sheet 5

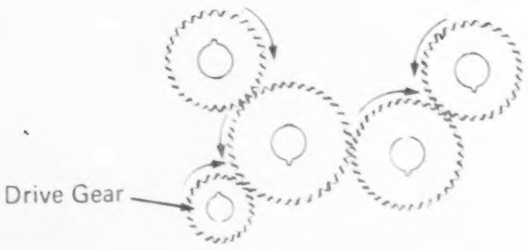
A.


Driving Gear

B.


Driving Gear

C.



Answers to Assignment Sheets

Assignment Sheet 6

	Rotation	Ratio	R.P.M.
A. Gear A	CC	2:1	1800
B. Gear B	C	.33:1	5400
C. Gear C	C	.80:1	2250
D. Gear D	CC	.83:1	2700
E. Gear E	CC	.16:1	7200
F. Gear F	CC	.40:1	3000
G. Gear G	C	.83:1	3600
H. Gear H	CC	.50:1	2400

Assignment Sheet 7—Evaluated according to criteria in the assignment sheet and to the instructor's satisfaction.

Assignment Sheet 8

A. 1. Limiting speed 3600 RPM
   2. Dynamic load rating 7500 lbs.
   3. Static load rating 9150 lbs.
   4. Select 9150 lb. static load as controlling factor—LS16
   5. The 11400 lb. dynamic limit will cover the 7500 lb. design load
   6. The 4000 RPM will cover the 3600 RPM design load
   7. LS16 bore size = 2¾"; outside diameter = 5¼"

B. 1. Limiting speed 2200 RPM
   2. Dynamic load rating 5500 lbs
   3. Static load rating 1800
   4. Select the 5500 lbs. as controlling factor—LS13
   5. The 3800 lb. static load will cover the 1800 lb. design load
   6. The 7100 RPM limiting speed will cover the 2200 RPM design load
   7. LS13 bore size = 1½"; outside diameter = 3¼"

Power Transmission: Gears, Bearings, and Cams
Unit 11

Answers to Written Test

1.

a.	3	f.	13	j.	11
b.	6	g.	1	k.	7
c.	8	h.	4	l.	5
d.	10	i.	9	m.	2
e.	12				

2.

a.	3	d.	2
b.	1	e.	2
c.	4	f.	2 or 3

3. a. Outside diameter
   b. Root diameter
   c. Circular thickness
   d. Circular pitch
   e. Addendum
   f. Dedendum
   g. Whole depth

4. a. Line of action
   b. Pressure angle
   c. Clearance
   d. Pitch circle
   e. Center distance

5. Any three of the following:

   a. Number of teeth
   b. Pitch diameter
   c. Dismetral pitch
   d. Pressure angle
   e. Whole depth
   f. Chordal addendum
   g. Chordal thickness

6. a. Pitch diameter
   b. Cone distance
   c. Back angle
   d. Backing

Answers to Written Test

7. Order may vary:
   - b. Number of teeth in gear
   - e. Addendum
   - i. Pinion
   - j. Gear
   - k. Thickness

8. a. Number
   - b. Pitch
   - c. Lead
   - d. Lead and direction
   - e. Diameter
   - f. Angle
   - g. Angle
   - h. Depth
   - i. Diameter

9. a. Number
   - b. Pitch
   - c. Diameter
   - d. Addendum
   - e. Depth
   - f. Number
   - g. Lead and direction
   - h. Angle
   - i. Angle
   - j. Throat
   - k. Outside
   - l. Radius
   - m. Rim
   - n. Width
   - o. Distance

10. a. 1.77:1
   - b. 3.16:1
   - c. .25:1

11. a. C
   - b. CC
   - c. CC
   - d. C

Answers to Written Test

12. a. 1250
    b. 625
    c. 1000
    d. 1875

13. Order may vary:

    a. Permanent
    b. Clutches

14. a. A
    b. P
    c. A or P
    d. A
    e. P

15. a. Pitch circle
    b. Base circle
    c. Follower
    d. Pressure angle

16. a. Roller
    b. Flat face

17. a. 2
    b. 4
    c. 1
    d. 4

Power Transmission: Gears, Bearings, and Cams
Unit 11

Written Test

Name ______________________ Date ______________ Score __________

1. Match the terms on the right with their correct definitions.

_______a. Machine parts used to lessen friction

_______b. A liner forced into a hole to provide a better wearing or bearing surface and to provide for easy replacement

_______c. Machine elements designed to produce a specific movement

_______d. A second motion or intermediate shaft in a power transmission system; also called a jack shaft

_______e. Devices for joining shafts together

_______f. A toothed wheel meshing with another toothed gear

_______g. The number of revolutions the drive gear must make to turn the driven gear one revolution

_______h. A combination of gears used to reduce the input speed to a lower output speed

_______i. A device which can act like a gear to fill up space and reverse direction, or act as a pulley to take up slack

_______j. Motion and function generators

_______k. Revolving components involved in the transmission of power from the engine to the drive wheel

1. Gear ratio
2. Splines
3. Bearings
4. Gear reduction
5. Seals
6. Bushing
7. Power train
8. Cams
9. Idler
10. Countershaft
11. Linkages
12. Couplings
13. Gear drive

Written Test

______l. Parts used to protect ball or roller bearings from loss of lubricant and the intrusion of dirt and dust on bearings

______m. Multiple keys in the general form of internal and external gear teeth, used to prevent rotation of a shaft

2. Match types of gears with their relation of axes positions. Place the number beside the axes positions in the blank beside the type of gear it describes.

______a. Worm and worm gear

______b. Plain bevel gear

______c. Rack and pinion gear

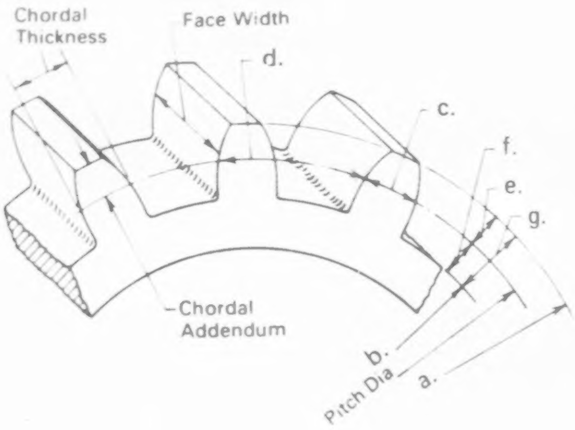
______d. Planetary gear

______e. Spur gear

______f. Helical gear

1. Axes intersect
2. Axes are parallel
3. Axes do not intersect
4. Axes do not intersect and straight line motion converts to circular motion or circular motion can convert to straight line motion

3. Identify parts of gear teeth. Write the name of the part in the appropriate blank.



a. ______________________ b. ______________________

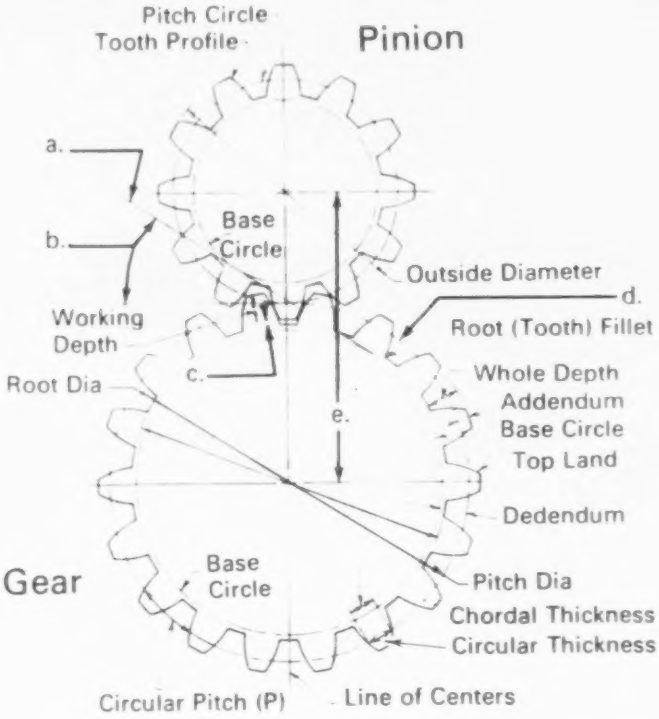
c. ______________________ d. ______________________

e. ______________________ f. ______________________

g. ______________________

Written Test

4. Identify parts of pinion and gear. Write the name of the part in the appropriate blank.


Pitch Circle
Tooth Profile
Pinion
a.
b.
Base Circle
Outside Diameter
d.
Working Depth
Root (Tooth) Fillet
c.
Root Dia
Whole Depth
Addendum
e.
Base Circle
Top Land
Dedendum
Gear
Base Circle
Pitch Dia
Chordal Thickness
Circular Thickness
Circular Pitch (P)
Line of Centers

a. ______________________ b. ______________________

c. ______________________ d. ______________________

e. ______________________

5. List three types of cutting data needed for spur gear drawings. Items may be written in any order.

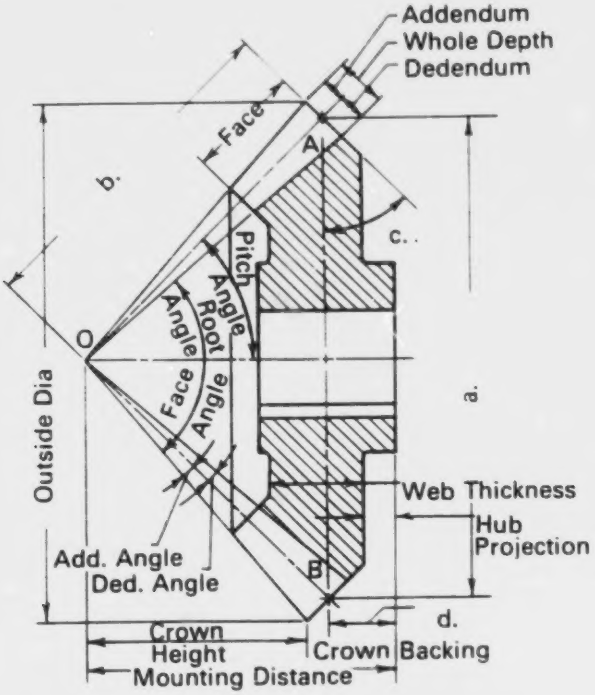
a. ____

b. ____

c. ____

Written Test

6. Identify parts of a bevel gear. Write the name of the part in the appropriate blank.


Addendum
Whole Depth
Dedendum
Face
A
b.
c.
Pitch Angle
Root Angle
Face Angle
O
Outside Dia
a.
Web Thickness
Hub Projection
Add. Angle
Ded. Angle
B
d.
Crown Height
Crown Backing
Mounting Distance

a. ____________________ b. ____________________

c. ____________________ d. ____________________

7. Complete the following list of cutting data needed for bevel gears. Write the missing items in the blanks provided.

a. Number of teeth in pinion

b. ____

c. Diametral pitch

d. Pressure angle

e. ____

f. Root angle

g. Face angle

Written Test

h. Whole depth

i. Chordal addendum for ______________________

j. Chordal addendum for ______________________

k. Chordal ______________________

8. Complete a list of cutting data needed for worm. Circle the material that best completes each of the following items.

   a. (**Size**) (**Number**) of threads.

   b. (**Pitch**) (**Angle**)

   c. (**Lead**) (**Size**)

   d. (**Lead and direction**) (**Lead and thread size**)

   e. Pitch (**length**) (**diameter**)

   f. Lead (**length**) (**angle**)

   g. Pressure (**angle**) (**in psi**)

   h. Whole (**size**) (**depth**)

   i. Outside (**angle**) (**diameter**)

9. Complete a list of cutting data needed for worm. Circle the material that best completes each of the following items.

   a. (**Size**) (**Number**) of threads

   b. (**Pitch**) (**Angle**)

   c. Pitch (**diameter**) (**size**)

   d. (**Addendum**) (**Pitch ratio**)

   e. Whole (**depth**) (**size**)

   f. (**Length**) (**Number**) of threads

   g. (**Lead and thread size**) (**Lead and direction**)

Written Test

h. Lead (**angle**) (**depth**)

i. Pressure (**in psi**) (**angle**)

j. (**Head**) (**Throat**) diameter

k. (**Inside**) (**Outside**) diameter

l. Throat (**depth**) (**radius**)

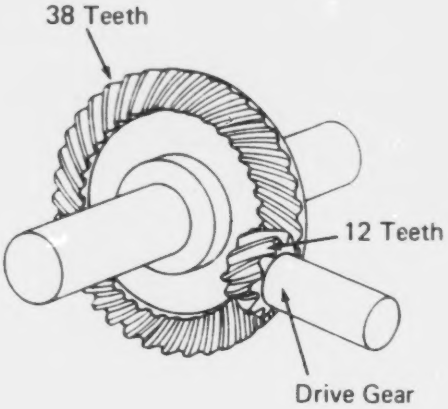
m. Radius of (**throat**) (**rim**)

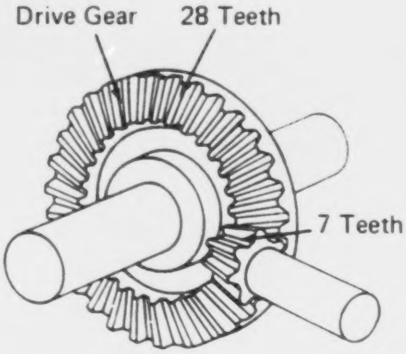
n. Face (**depth**) (**width**)

o. Center (**angle**) (**distance**)

10. Calculate gear ratios in the following problem and illustrations. Write the correct answers in the blanks provided.

a. Driven gear has 64 teeth
Driving gear has 36 teeth ______________________________


38 Teeth
12 Teeth
Drive Gear


Drive Gear
28 Teeth
7 Teeth

b. ______________________________ c. ______________________________

Written Test

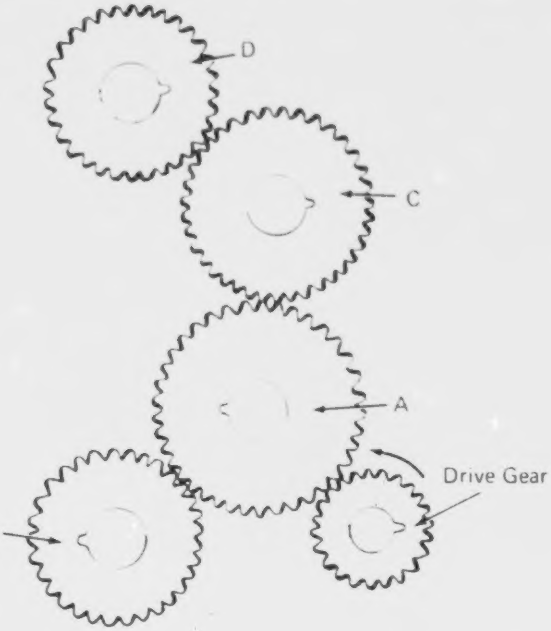
11. Determine gear rotation in the following illustration. Place a "C" to indicate clockwise rotation and a "CC" to indicate counterclockwise rotation.

______a. Gear A

______b. Gear B

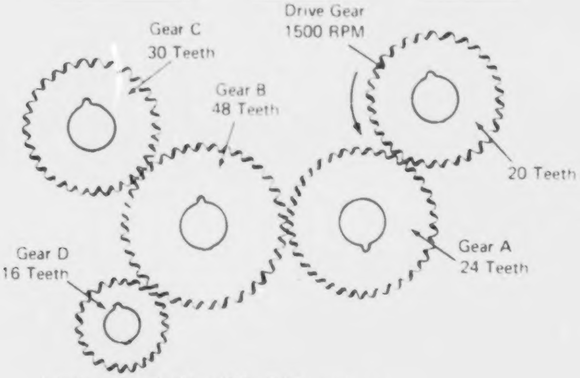
______c. Gear C

______d. Gear D


D
C
A
Drive Gear
B

12. Calculate gear speed in the following illustration. Write the appropriate RPM in the blanks provided.

		Rotation	Ratio	RPM
a.	Gear A	C	1.20:1	
b.	Gear B	CC	2:1	
c.	Gear C	C	.63:1	
d.	Gear D	C	.33:1	


Gear C
30 Teeth
Gear B
48 Teeth
Drive Gear
1500 RPM
20 Teeth
Gear D
16 Teeth
Gear A
24 Teeth

Written Test

13. List two types of couplings. Write your entries in the blanks provided.

    a. ______________________________

    b. ______________________________

14. Differentiate between types of bearings. Place a "P" in the blanks beside plain bearings and an "A" in the blanks beside antifriction bearings.

    ______a. Ball

    ______b. Radial

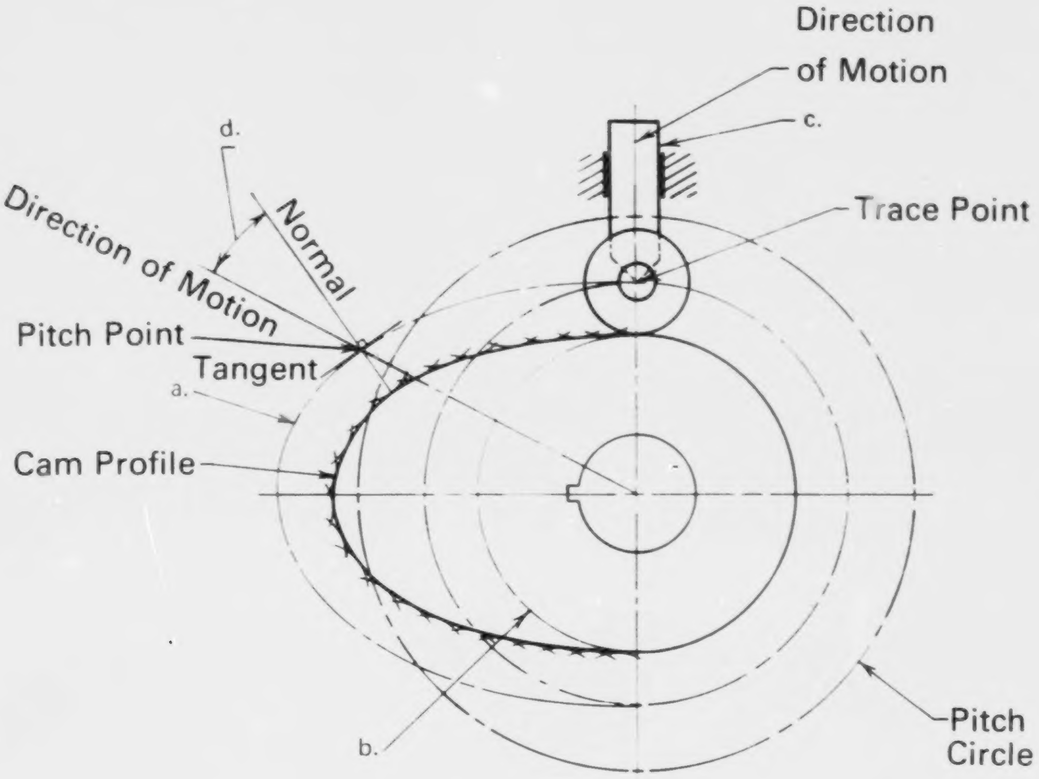
    ______c. Thrust

    ______d. Roller

    ______e. Guide or slipper

Written Test

15. Identify calm nomenclature in the following illustration. Write the correct nomenclature in the blanks provided.



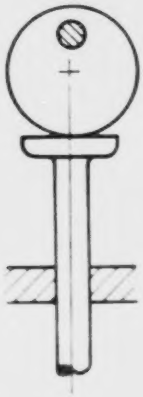
Direction of Motion
c.
d.
Trace Point
Direction of Motion
Normal
Pitch Point
Tangent
a.
Cam Profile
b.
Pitch Circle

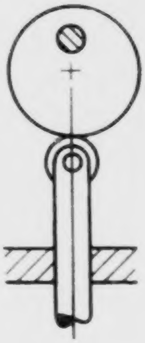
a. ____________________ b. ____________________

c. ____________________ d. ____________________

Written Test

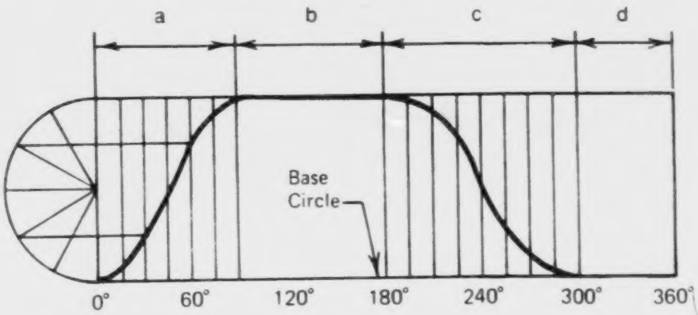
16. Identify types of cam followers in the illustrations below. Write the name of the follower in the blank provided.





a. ______________________ b. ______________________

17. Identify types of cam motions. On the following illustration, select the type of motion demonstrated in the lettered segments a, b, c, and d, and place the number that identifies the motion in the appropriate blank.



a. ______ 1. Uniform motion

b. ______ 2. Harmonic motion

c. ______ 3. Parabolic motion

d. ______ 4. Dwell

***Permission to duplicate this test is granted.**

Power Transmission: Gears, Bearings, and Cams
Unit 11

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Construct A Spur Gear Drawing Rating ______

Comments: ____

____

Assignment Sheet 2—Construct A Bevel Gear Drawing Rating ______

Comments: ____

____

Assignment Sheet 3—Construct A Worm and Worm Gear Drawing Rating ______

Comments: ____

____

Assignment Sheet 4—Calculate Gear Ratios Rating ______

Comments: ____

____

Assignment Sheet 5—Determine Gear Rotation Rating ______

Comments: ____

____

Assignment Sheet 6—Calculate Gear Speeds Rating ______

Comments: ____

____

Unit Evaluation Form

Assignment Sheet 7—Construct A Cam Drawing Rating ______

Comments: ____

____

Assignment Sheet 8—Select Types of Bearings From Handbooks Rating ______

Comments: ____

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

Teacher Signature ______________________ Date __________

Student Signature ______________________ Date __________

*Permission to duplicate this form is granted.

Power Transmission: Gears, Bearings, and Cams
Unit 11

Information Sheet

1. **Terms and definitions**

   a. **Bearings** — Machine parts used to lessen friction

   b. **Bushing** — A liner forced into a hole to provide a better wearing or bearing surface and to provide for easy replacement

   c. **Cams** — Machine elements designed to produce a specific movement

   d. **Countershaft** — A second motion or intermediate shaft in a power transmission system; also called a jack shaft

   e. **Couplings** — Devices for jointing shafts together

   f. **Gear drive** — A toothed wheel meshing with another toothed gear

   g. **Gear ratio** — The number of revolutions the drive gear must make to turn the driven gear one revolution

   h. **Gear reduction** — A combination of gears used to reduce the input speed to a lower output speed

   i. **Idler** — A device which can act like a gear to fill up space and reverse direction, or act as a pulley to take up slack

   j. **Linkages** — Motion and function generators

   k. **Power train** — Revolving components involved in the transmission of power from the engine to the drive wheel

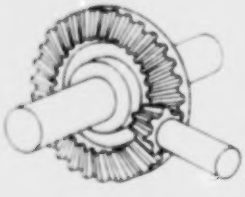
   l. **Seals** — Parts used to protect ball or roller bearings from loss of lubricant and the intrusion of dirt and dust on bearings

   m. **Splines** — Multiple keys in the general form of internal and external gear teeth, used to prevent rotation of a shaft

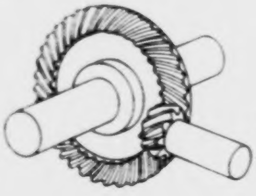
Information Sheet

2. Types of gears and their relation of axes positions

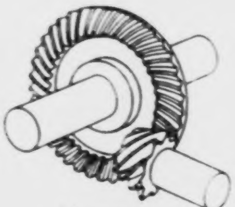
a. The spiral bevel (miter) gear, the plain (straight) bevel gear, and the hypoid gear all have axes that intersect.



Plain Bevel

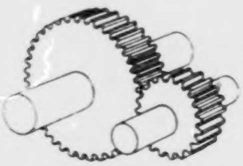


Spiral Bevel

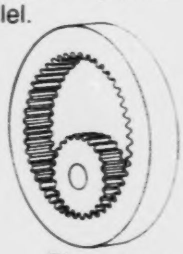


Hypoid

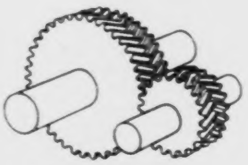
b. The spur gear, helical gear, planetary (internal) gear, and the herringbone gear all have axes that are parallel.



Straight Spur

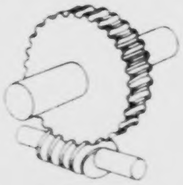


Planetary

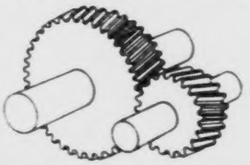


Herringbone

c. The worm and worm gear and the helical gear have axes that do not intersect.

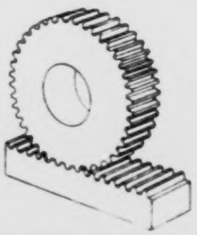


Worm



Helical Spur

d. Rack and pinion gear have axes that do not intersect and straight line motion converts to circular motion, or circular motion can convert to straight line motion.



Rack and Pinion

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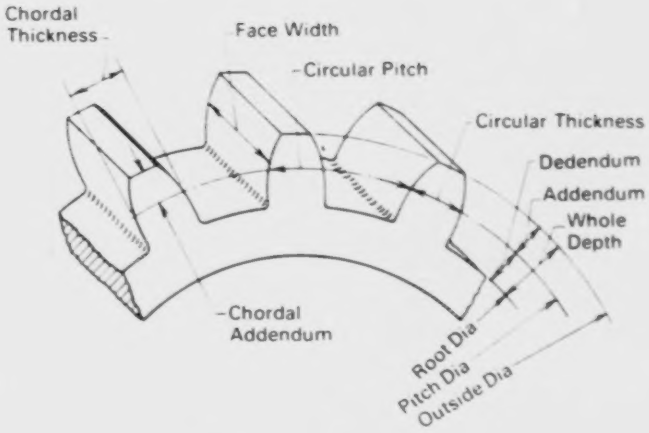
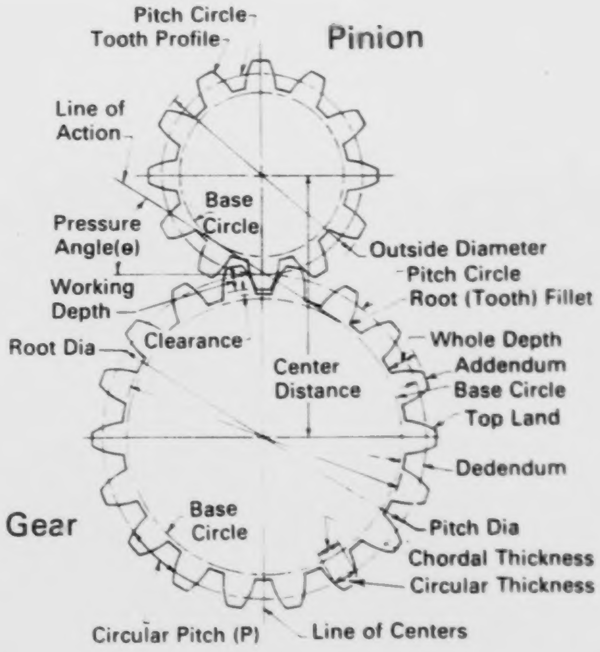
Information Sheet

3. **Parts of gear teeth**
    - a. Face width
    - b. Circular pitch
    - c. Circular thickness
    - d. Dedendum
    - e. Addendum
    - f. Whole depth
    - g. Chordal addendum
    - h. Root diameter
    - i. Pitch diameter
    - j. Outside diameter


Chordal Thickness
Face Width
Circular Pitch
Circular Thickness
Dedendum
Addendum
Whole Depth
Chordal Addendum
Root Dia
Pitch Dia
Outside Dia

4. **Parts of pinion and gear**
    - a. Line of action
    - b. Pressure angle
    - c. Clearance
    - d. Working depth
    - e. Center distance
    - f. Pitch circle


Pitch Circle
Tooth Profile
Pinion
Line of Action
Base Circle
Pressure Angle(θ)
Outside Diameter
Pitch Circle
Root (Tooth) Fillet
Working Depth
Root Dia
Clearance
Whole Depth
Addendum
Center Distance
Base Circle
Top Land
Dedendum
Gear
Base Circle
Pitch Dia
Chordal Thickness
Circular Thickness
Circular Pitch (P)
Line of Centers

Information Sheet

5. Cutting data needed for spur gear drawings

a. Number of teeth

Formula: Number of teeth = Pitch diameter × Diametral pitch

b. Pitch diameter

Formula: $\text{Pitch diameter} = \dfrac{\text{Number of teeth}}{\text{Diametral pitch}}$

c. Diametral pitch

Formula: $\text{Diametral pitch} = \dfrac{\text{Number of teeth}}{\text{Pitch diameter}}$

d. Pressure angle

Formula: Pressure angle = 12 1/2° or 20°

e. Tooth form—Specify as:

- (1) Standard addendum
- (2) Long addendum
- (3) Short addendum
- (4) Modified involute or special

f. Whole depth (optional)

Formula: whole depth = addendum + dedendum

g. Chordal addendum (optional)

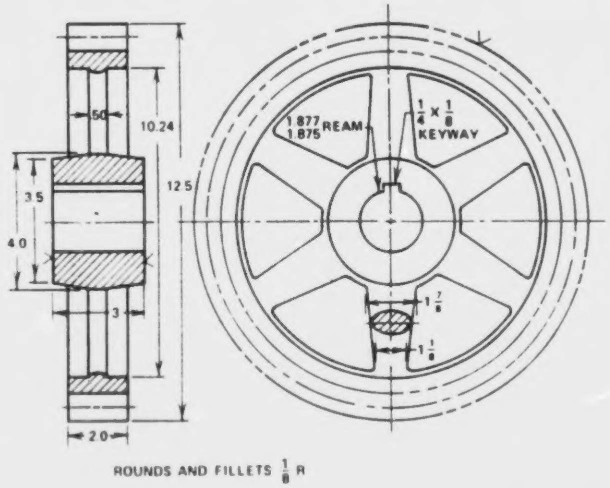
Formula:

$$\text{Chordal addendum} = \text{Addendum} + \frac{(1.57/\text{Diametral pitch})^2}{4(\text{Pitch diameter})} = \frac{1}{\text{Diametral Pitch}}$$

Information Sheet

h. Chordal thickness (optional)

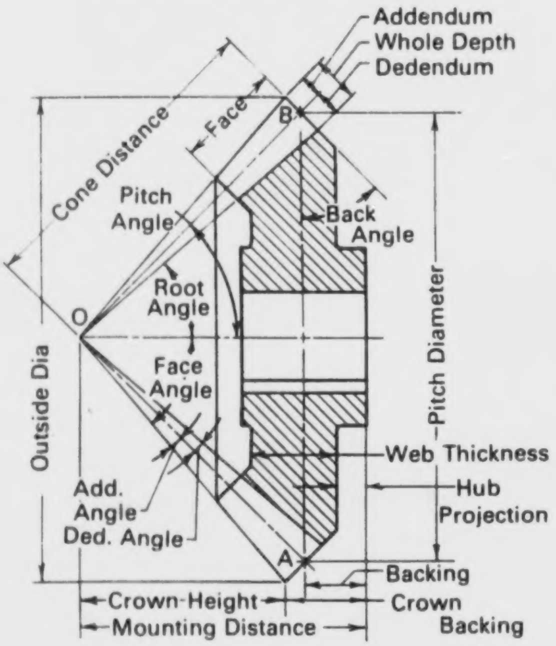
Formula: Chordal thickness $= \dfrac{1.5708}{\text{Diametral Pitch}}$


.50
10.24
12.5
3.5
4.0
3
2.0
1.877
1.875 REAM
1/4 × 1/8 KEYWAY
1 7/8
1 1/8
ROUNDS AND FILLETS 1/8 R

CUTTING DATA	
NO. OF TEETH	48
PITCH DIAMETER	12.00
DIA PITCH	4.00
PRESSURE ANGLE	14½°
WHOLE DEPTH	.5395
CHORDAL ADD	.25
CHORDAL THICK	.3927
WORKING DEPTH	.5000
CIRCULAR THICK	.3927

6. **Parts of a bevel gear**
   a. Cone distance
   b. Face
   c. Back angle
   d. Pitch diameter
   e. Crown backing
   f. Backing
   g. Mounting distance
   h. Addendum angle
   i. Dedendum angle
   j. Outside DIA
   k. Pitch angle

Bevel Gear Nomenclature


Addendum
Whole Depth
Dedendum
Cone Distance
Face
B
Pitch Angle
Back Angle
Root Angle
O
Face Angle
Outside Dia
Pitch Diameter
Web Thickness
Hub Projection
Add. Angle
Ded. Angle
A
Backing
Crown-Height
Mounting Distance
Crown Backing

Information Sheet

l. Root angle

m. Face Angle

n. Addendum

o. Whole depth

p. Dedendum

q. Pinion-Smaller of mating gears

Note: See ANSI *Bb.13 - 1965* for more details.

7. **Cutting data needed for bevel gears**

a. Number of teeth in pinion—n

b. Number of teeth in gear—N

c. Diametral pitch—P

d. Pressure angle and form—Basic is 20° = ϕ

Note: 14 1/2° pressure angle can be used, but certain combinations of teeth must be used to avoid undercutting.

e. Addendum for gear = $\frac{\text{1 or select from table}}{\text{Diametral pitch}}$

f. Addendum—for pinion = Working depth – Addendum for gear

g. Addendum—a = $\frac{1}{\text{Diametral pitch}} = \frac{1}{P}$

h. Root angle—R = Pitch angle – Dedendum angle

i. Face angle—F = Pitch angle – Addendum angle

j. Whole depth—W = $\frac{2.188}{P} + .002$

Note: This is the same for pinion and gear

Information Sheet

k. choral Addendum for Pinion—Cp = Addendum for Pinion +

$$\frac{(\text{Circular thickness for pinion})^2 \times \text{Cosine of pitch angle of pinion}}{4 \times \text{Pitch diameter of pinion}}$$

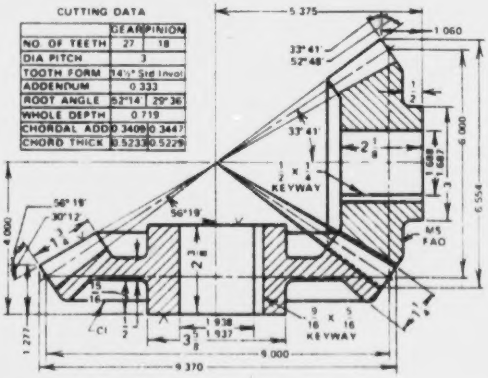
l. Chordal Addendum for Gear—C_G = Addendum for gear +

$$\frac{(\text{Circular thickness for gear})^2 \times \text{Cosine of pitch angle of gear}}{4 \times \text{Pitch diameter of gear}}$$

m. Chordal Thickness—C_T = Circular thickness of Pinion –

$$\frac{(\text{Circular thickness of Pinion})^3}{6(\text{Pitch diameter of Pinion})^2} - \frac{\text{Backlash}}{2}$$

Note: Select backlash value from table in *Machinery's Handbook*.



CUTTING DATA

	GEAR	PINION
NO OF TEETH	27	18
DIA PITCH	3	
TOOTH FORM	14½° Std Invol	
ADDENDUM	0 333	
ROOT ANGLE	52°14'	29°36'
WHOLE DEPTH	0 719	
CHORDAL ADD	0 3409	0 3447
CHORD THICK	0 5233	0 5229

5 375
1 060
33°41'
52°48'
33°41'
1 × 1 KEYWAY
MS FAO
6 000
6 554
56°19'
30°12'
56°19'
4 000
1 277
CI
1 938
1 937
9 × 5 KEYWAY
9 000
9 370

8. Cutting data needed for worm

Note: Examples are for double threads.

a. Number of threads = t

Example: t = 2

b. Pitch = P = $\frac{\text{Lead}}{\text{Number of threads}} = \frac{L}{t}$

Information Sheet

c. Lead = L = Number of threads in worm (Pitch); L = tP

Example: $L = 2(.625) = 1.25$

d. Lead and direction—Distance thread travels in one revolution, RH or LH; single thread lead = L = 1; double thread lead = L = 2

e. Pitch diameter = d = Outside dia worm − 2 (addendum) = $d = d_o$

Example: $d = d_o - 2a = 2.931 - 2\,(.199) = 2.533$

f. Lead angle = La = helix angle measured from a plane perpendicular to worm axis

Example: La = 8° 56′

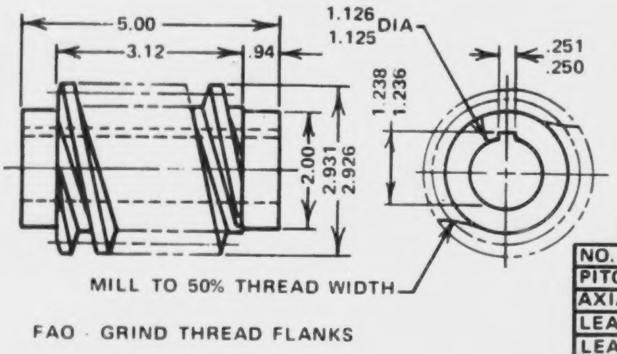
g. Pressure angle = 14 1/2°

h. Whole depth = W = .686 (Pitch) = .686P

Example: $W = .686P = .686\,(.625) = .429$

i. Outside diameter = d_o = pitch dia + 2 (addendum) $d_o = P + 2a$

Example: $d_o = P + 2a = 2.533 + 2\,(.199)$; $d_0 = 2.931$


5.00
3.12
.94
1.126
1.125
DIA
.251
.250
1.238
1.236
2.00
2.931
2.926
MILL TO 50% THREAD WIDTH
FAO · GRIND THREAD FLANKS

Worm

CUTTING DATA

NO. OF THREADS	2
PITCH DIA	2.533
AXIAL PITCH	0.625
LEAD · RH	1.250
LEAD ANGLE	8°56′
PRESSURE ANGLE	14½°
WHOLE DEPTH	0.429

Information Sheet

9. Cutting data needed for worm gear

Note: Examples are for double threads.

a. Number of teeth = T

Example: $T = 30$

b. $\text{Pitch} = P = \dfrac{\text{Lead}}{{}^{*}\text{Number of threads}} = \dfrac{L}{t}$

* Double threads = 2

c. $\text{Pitch diameter} = D = \dfrac{\text{Pitch(Number of teeth)}}{3.1416} = \dfrac{PT}{3.1416}$

Example: $D = \dfrac{PT}{3.1416} = \dfrac{(.625)\ (30)}{3.1416} = 5.9683$

d. Addendum = $a = .3183\ (\text{Pitch}) = .3183P$

Example: $a = .3183P = .3183\ (.625) = .199$

e. Whole depth = $W = .686(\text{Pitch}) = .686P$

Example: $W = .686P = .683\ (.625) = .429$

f. Number of threads = t

g. Lead and direction—Distance thread moves in one turn, RH or LH; single thread L and = L = 1; double thread L and = L = 2

Example: Double thread = L = 2

h. Lead angle = L_a = Helix angle measured from a plane perpendicular to worm axis

Example: Lead angle = 8°56′

i. Pressure angle = 14 1/2° to 30°

Example: pressure angle = 14 1/2°

Information Sheet

j. Throat diameter = D_t = Pitch diameter + 2(Addendum) = $D_t = D + 2(a)$

Example: $D + 2(a) = 5.9683 + 2(.199) = 6.366$

k. Outside diameter = $D_0 = D_t + .4775P = 6.366 + .4775(.625) = 6.664$

l. Throat radius = $R_t = \dfrac{\text{Outside Diameter } -2 \text{ (Addendum)}}{2} = R_t = \dfrac{D_0 \; -2(a)}{2}$

Example: $R_t = \dfrac{6.664 \; -2(.199)}{2} = 2.934$

m. Radius of Rim = R_r = .25(Pitch) = .25P

Example: $R_r = .25P = .25(.625) = .156$

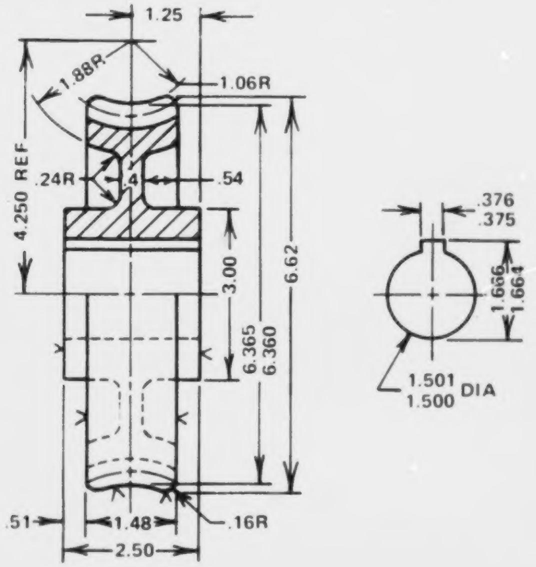
n. Face width = F = 2.38(Pitch) + .25 = 2.38P + .25

Example: $F = 2.38P + .25 = 2.38(.625) + .25 = 1.738$

o. Center distance =

$$\frac{\text{Pitch Dia of Worm Gear + Pitch Dia of Worm}}{2} = C = \frac{D + d}{2}$$

Example: $C = \dfrac{D + d}{2} = \dfrac{5.9683 + 2.533}{2} = 4.2506$


1.25
1.88R
1.06R
.24R
.54
4.250 REF
3.00
6.62
6.365
6.360
.51
1.48
.16R
2.50
.376
.375
1.666
1.664
1.501
1.500 DIA

Worm Gear

CUTTING DATA

NO. OF TEETH	30
PITCH DIA	5.967
ADDENDUM	0.199
WHOLE DEPTH	0.429
NO. of THREADS	2
AXIAL PITCH	0.625
LEAD - RH	1.250
LEAD ANGLE	8° 56′
PRESS. ANGLE	14½°

Information Sheet

10. Guidelines for calculating gear ratios

a. Count and record the number of teeth on the driving gear.

b. Count and record the number of teeth on the driven gear.

c. Divide the number of teeth on the driven gear by the number of teeth on the driving gear.

Example: If a driven gear has 60 teeth and a driving gear has 20 teeth, the gear ratio is 60 ÷ 20 = 3.

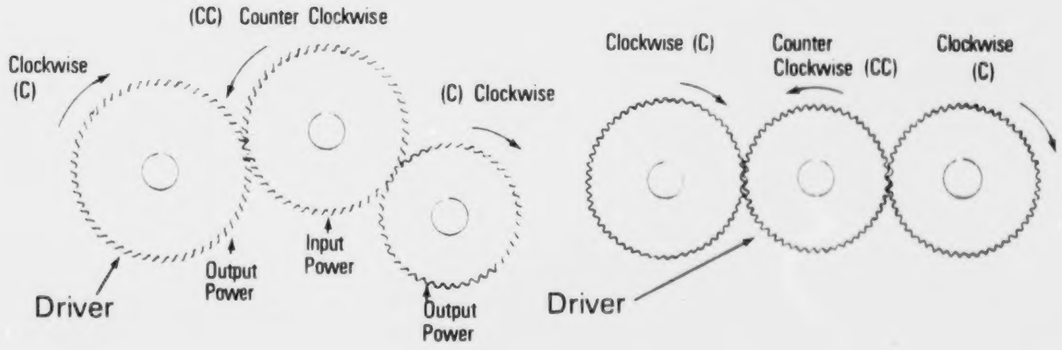
d. Express the ratio with proper notation such as 3:1, 2:1, or 1.87:1.

Example: In the conditions stated in C. the gear ratio is 3:1.

11. Guidelines for determining gear rotation

a. Gears are used to change the direction of transmitted power.

b. Determine gear rotation with a driving gear turning clockwise, and the driving gear drives a driven gear counterclockwise in the opposite direction.

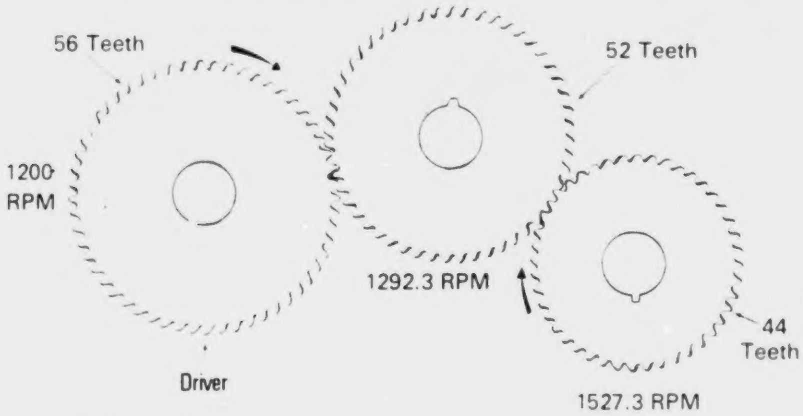

(CC) Counter Clockwise
Clockwise (C)
(C) Clockwise
Output Power
Input Power
Output Power
Driver
Clockwise (C)
Counter Clockwise (CC)
Clockwise (C)
Driver

12. Guidelines for calculating gear speed

a. A small gear will drive a large gear more slowly, but with greater torque, and a large gear will drive a small gear faster with less torque.

Information Sheet

b. The formula to calculate gear speed is: R.P.M. × No. of teeth of driving gear = R.P.M. × No. of teeth of driven gear.


56 Teeth
52 Teeth
1200 RPM
1292.3 RPM
44 Teeth
Driver
1527.3 RPM

13. **Types of couplings**

    a. Permanent

    Example: Flexible, solid, universal, and fluid

    b. Clutches

    Example: mechanical, electric, hydraulic

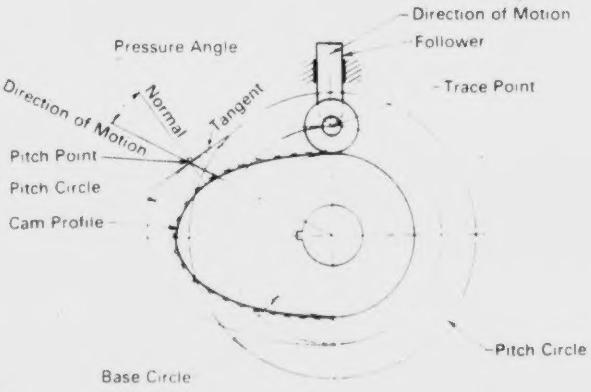
14. **Type of bearings**

    a. Plain bearings include radial, thrust, and guide or slipper bearings.

    b. Antifriction bearings include ball, roller, needle, and thrust bearings.

15. **Cam nomenclature**

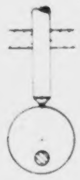
    a. Follower
    b. Base circle
    c. Pressure angle
    d. Trace point
    e. Prime circle
    f. Pitch circle
    g. Direction of motion


Direction of Motion
Follower
Pressure Angle
Trace Point
Direction of Motion
Normal
Tangent
Pitch Point
Pitch Circle
Cam Profile
Pitch Circle
Base Circle

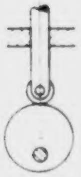
Information Sheet

16. Types of cam followers

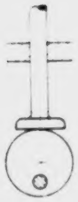
a. Pointed



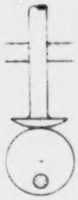
b. Roller



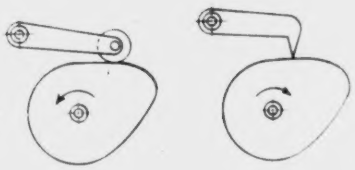
c. Flat face



d. Special

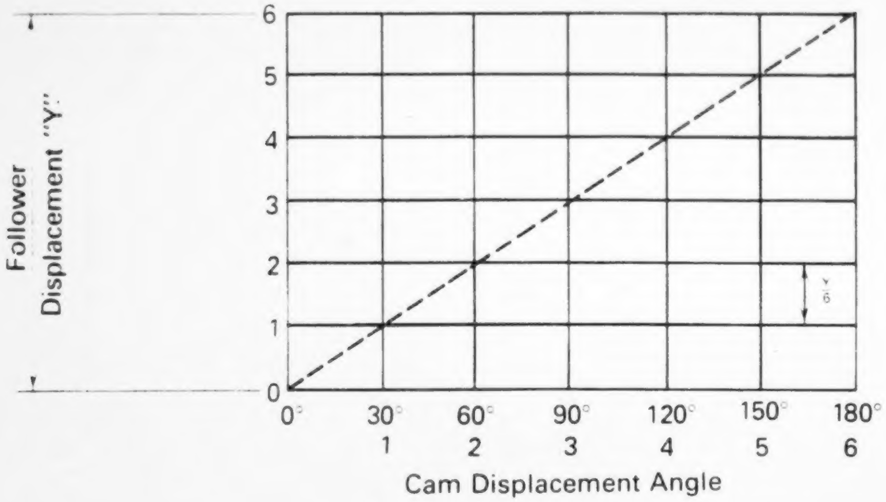


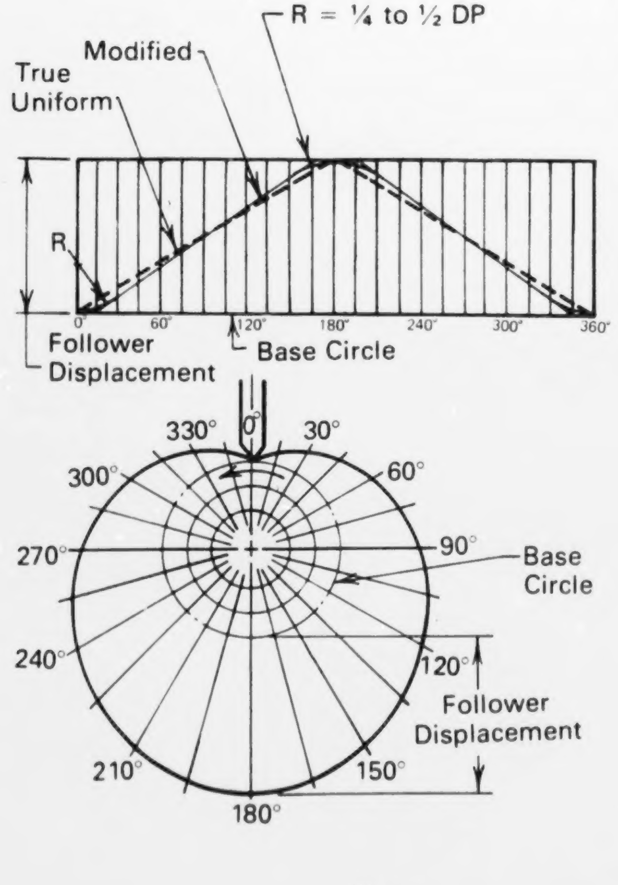
e. Swinging



17. Types of cam motions

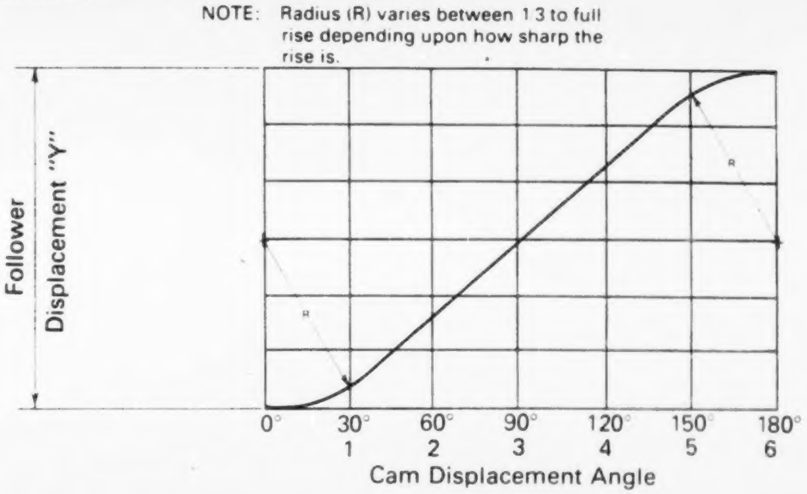
a. Uniform



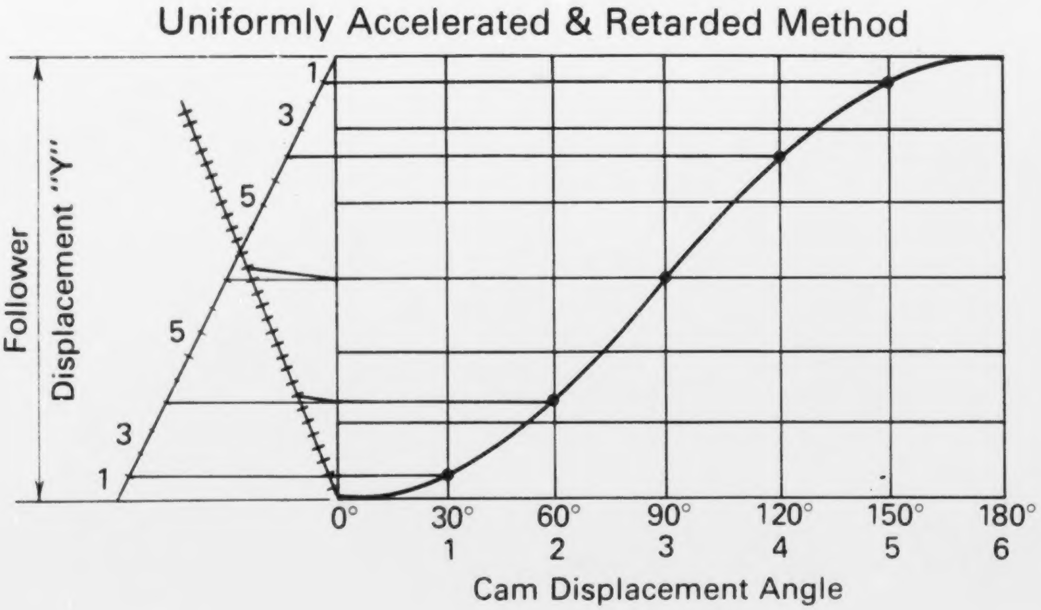

R = ¼ to ½ DP
Modified
True
Uniform
R
0°
60°
120°
180°
240°
300°
360°
Follower
Displacement
Base Circle
330°
0°
30°
300°
60°
270°
90°
Base
Circle
240°
120°
Follower
Displacement
210°
150°
180°

Information Sheet

b. Modified

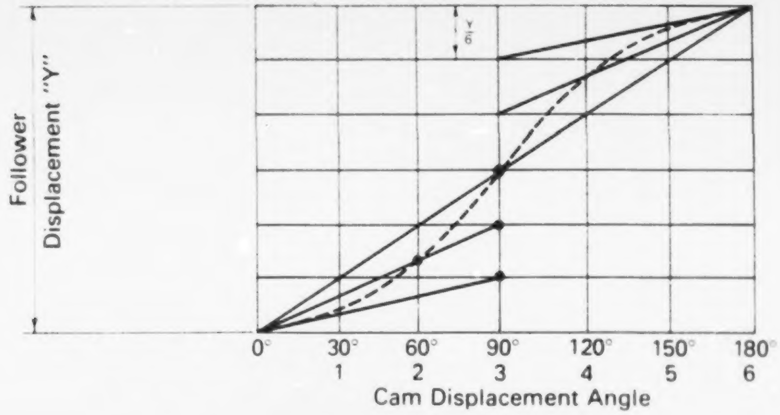

NOTE: Radius (R) varies between 1 3 to full rise depending upon how sharp the rise is.
Follower Displacement "Y"
R
R
0°
30° 1
60° 2
90° 3
120° 4
150° 5
180° 6
Cam Displacement Angle

c. Parabolic including uniformly accelerated and retarded method and the constructed method.

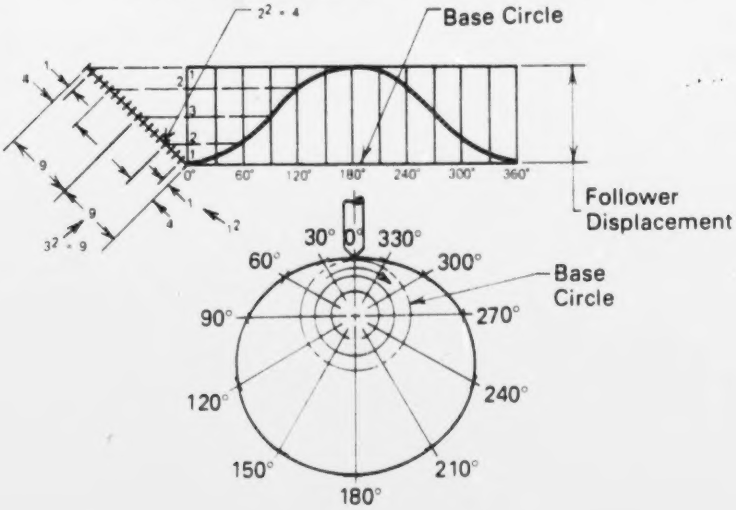

Uniformly Accelerated & Retarded Method
Follower Displacement "Y"
1
3
5
5
3
1
0°
30° 1
60° 2
90° 3
120° 4
150° 5
180° 6
Cam Displacement Angle

Information Sheet

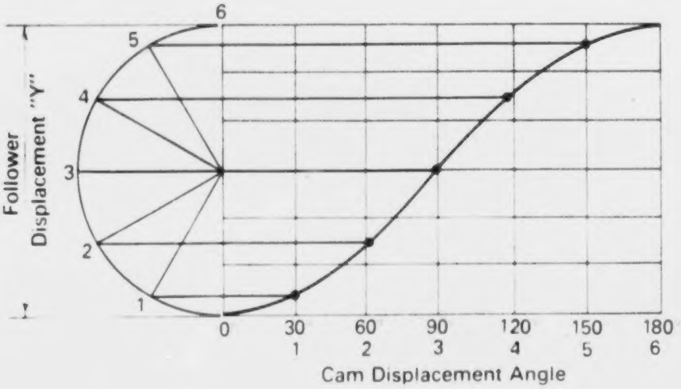
Construction Method


Y/6
Follower Displacement "Y"
0°
30°
1
60°
2
90°
3
120°
4
150°
5
180°
6
Cam Displacement Angle

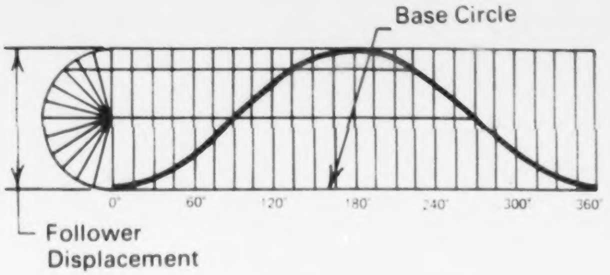
Parabolic Motion - Cam Profile

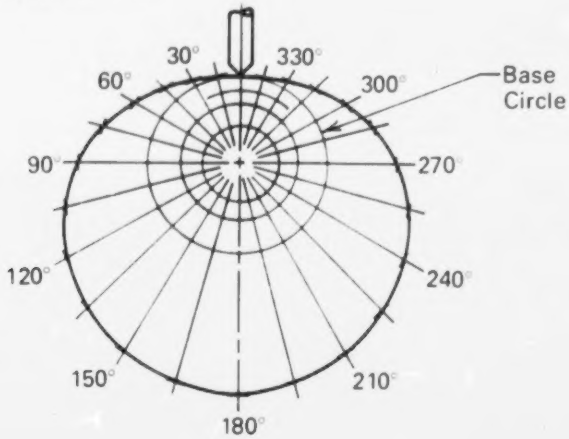

2² = 4
Base Circle
4
1
9
9
3² = 9
1
4
1
2
3
2
1
1
2
0°
60°
120°
180°
240°
300°
360°
Follower Displacement
30°
0°
330°
60°
300°
Base Circle
90°
270°
120°
240°
150°
210°
180°

d. Harmonic

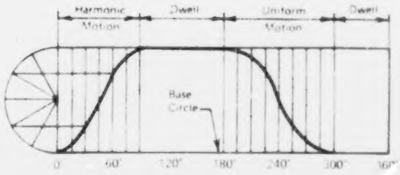

6
5
4
3
2
1
Follower Displacement "Y"
0
30
1
60
2
90
3
120
4
150
5
180
6
Cam Displacement Angle

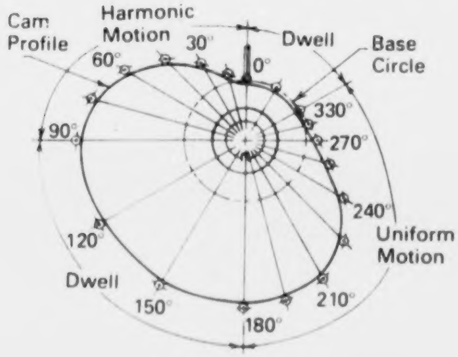
Information Sheet


Base Circle
0°
60°
120°
180°
240°
300°
360°
Follower
Displacement


30°
330°
60°
300°
Base
Circle
90°
270°
120°
240°
150°
210°
180°

e. Combination


Harmonic
Motion
Dwell
Uniform
Motion
Dwell
Base
Circle
0°
60°
120°
180°
240°
300°
360°


Cam
Profile
Harmonic
Motion
30°
Dwell
Base
Circle
60°
0°
330°
90°
270°
240°
Uniform
Motion
120°
Dwell
150°
210°
180°

Power Transmission: Gears, Bearings, and Cams
Unit 11

Assignment Sheet 1—Construct a Spur Gear Drawing

Name ______________________ Overall Rating __________

Evaluation criteria	**Rating**
Problem A solutions	______
Cutting data for Problem A	______
Problem B solutions	______
Cutting data for Problem B	______

Directions: Select one of the following problems, and construct a spur gear drawing as shown in the example. Use "B" size vellum or other media assigned by instructor. Include cutting data table and dimensions. Use the following formulas to solve the incomplete cutting data in the problems:

> **CAD Alert:** Use your CAD system with third-party software for constructing spur gears. Construct gears with data from your own calculations, and then compare your results with the results generated by CAD.

1. No. of teeth = Pitch diameter × Diametral pitch
2. Pitch diameter = $\frac{\text{No. of teeth}}{\text{Diametral pitch}}$
3. Diametral pitch = $\frac{\text{No. of teeth}}{\text{Pitch diameter}}$
4. Whole depth = $\frac{2.157}{\text{Diametral pitch}}$

Assignment Sheet 1

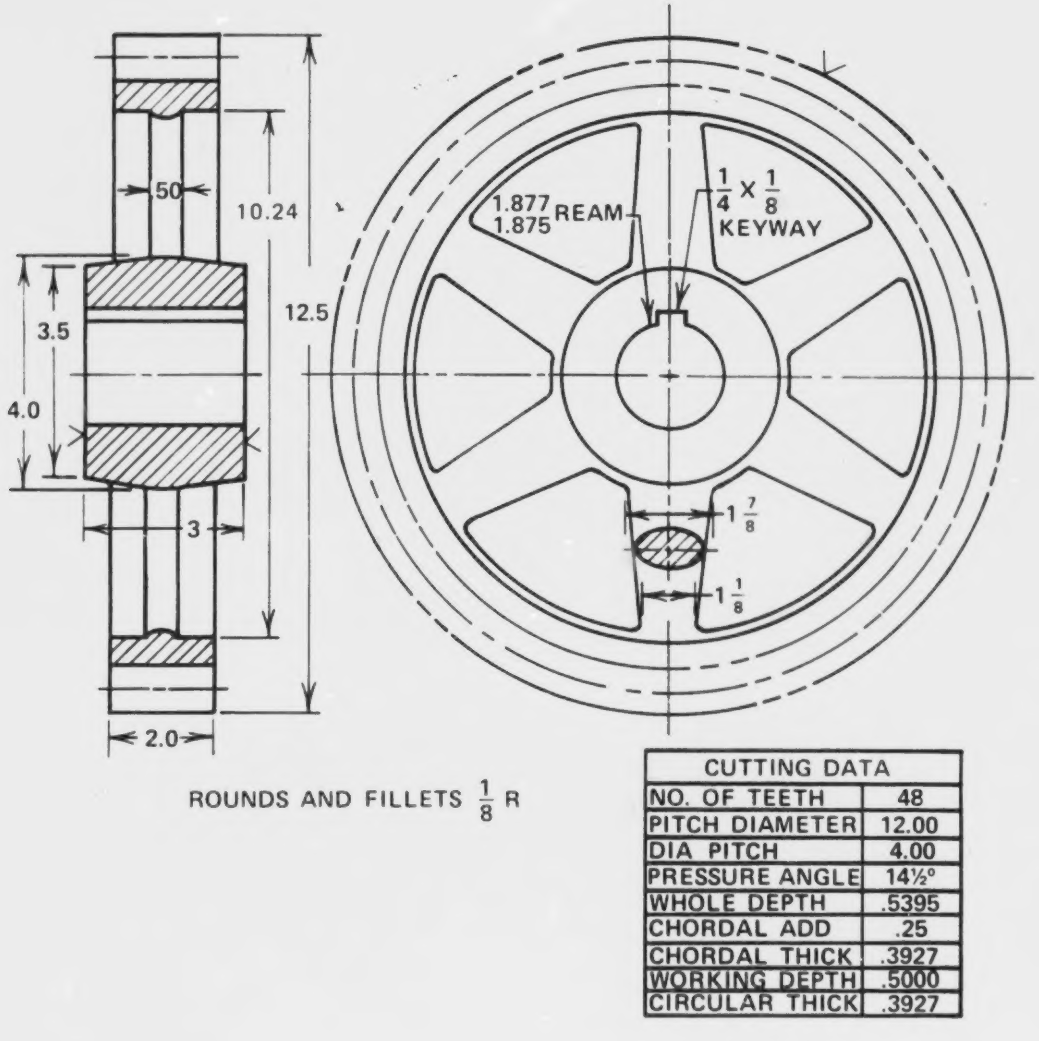
5. Chordal addendum = Addendum + $\frac{(1.57/\text{Diametral pitch})^2}{4\ (\text{Pitch diameter})}$

6. Chordal thickness = Pitch diameter $\frac{(\text{Sin } 90^\circ)}{\text{No. of teeth}}$

Note: Your instructor may wish for you to do both problems or assign another problem.

Assignment Sheet 1

Example:


.50
10.24
12.5
3.5
4.0
3
2.0
1.877
1.875 REAM
1/4 X 1/8
KEYWAY
1 7/8
1 1/8

ROUNDS AND FILLETS $\frac{1}{8}$ R

CUTTING DATA	
NO. OF TEETH	48
PITCH DIAMETER	12.00
DIA PITCH	4.00
PRESSURE ANGLE	14½°
WHOLE DEPTH	.5395
CHORDAL ADD	.25
CHORDAL THICK	.3927
WORKING DEPTH	.5000
CIRCULAR THICK	.3927

Assignment Sheet 1

Problems:

A. Spur gear

1. Hub thickness—1.5″
2. Hub diameter—2.19″ at crown
3. Hub diameter—2″ at face
4. Web thickness—.31″
5. Web width at hub—.75″
6. Outside diameter—6.4
7. Inside diameter—5.0
8. Ream—1.000/1.002 and keyway—1/4 × 1/8
9. Cutting data
    a. Number of teeth—30
    b. Pitch diameter—6.000
    c. Diametral pitch—5.0
    d. pressure angle—14 1/2°
    e. Whole depth—.431
    f. Chordal addendum ______________________________

B. Spur gear

1. Hub thickness—2.00
2. Hub diameter—3.00 at crown
3. Hub diameter—2.85 at face
4. Web thickness—.50
5. Web width at hub—1.50
6. Web width at gears—.88

Assignment Sheet 1

7. Outside diameter—12.25

8. Inside diameter—8.5

9. Cutting data

   a. Number of teeth—96

   b. Pitch diameter ______________________________

   c. Diametral pitch—8

   d. Pressure angle—14 1/2°

   e. Whole depth ______________________________

   f. Chordal addendum ______________________________

Power Transmission: Gears, Bearings, and Cams
Unit 11

Assignment Sheet 2—Construct a Bevel Gear Drawing

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Bevel gear drawing	_____
Cutting table data	_____

Directions: On "B" size vellum or other media assigned by instructor, construct a bevel gear drawing from the information in problem A. Include a cutting data table and dimensions as shown in the example. On a second sheet of vellum or other media, complete the information in problem B. Use the following formulas to complete the date in problem B.

1. Number of teeth in pinion—n
2. Number of teeth in gear—N
3. Diametral pitch—P
4. Pressure angle and form—Basic is 20° = ϕ

   Note: 14 1/2° pressure angle can be used, but certain combinations of teeth must be used to avoid undercutting.

5. Addendum for gear = $\dfrac{\text{1 or select from table}}{\text{Diametral pitch}}$
6. Addendum for pinion = Working depth — Addendum for gear
7. Addendum—a = $\dfrac{1}{\text{Diametral pitch}}$
8. Root angle—R = Pitch angle − Dedendum angle
9. Face angle—F = Pitch angle − Addendum angle
10. Whole depth—W = Addendum + Dedendum

    Note: This is the same for pinion and gear.

Assignment Sheet 2

11. Chordal Addendum for Pinion—Cp = Addendum for pinion +

$$\frac{\text{Circular thickness for pinion} \times \text{Cosine of pitch angle of pinion}}{4 \times \text{Pitch diameter of pinion}}$$

12. Chordal Addendum for Gear—C_G = Addendum for gear +

$$\frac{\text{Circular thickness for gear — Cosine of pitch angle of pinion}}{4 \times \text{Pitch diameter of gear}}$$

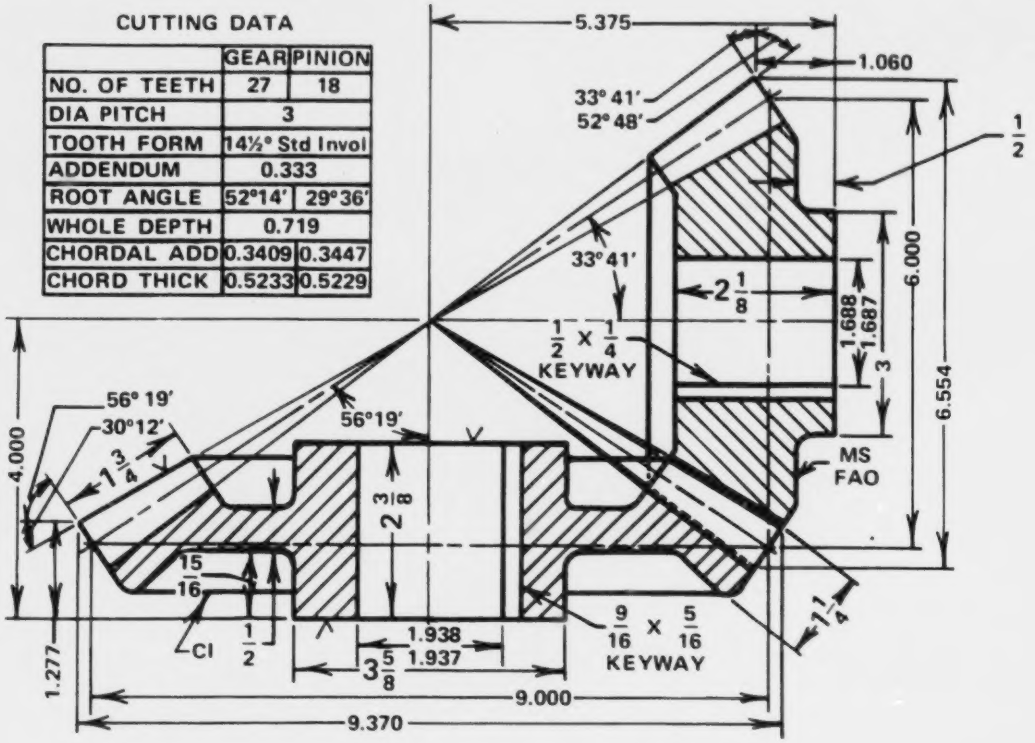
13. Chordal Thickness—C_T = Circular thickness of pinion —

$$\frac{(\text{Circular thickness of pinion})^3}{6(\text{Pitch diameter of pinion})^2} - \frac{\text{Select from Table}}{2}$$

Example:

CUTTING DATA

	GEAR	PINION
NO. OF TEETH	27	18
DIA PITCH	3	
TOOTH FORM	14½° Std Invol	
ADDENDUM	0.333	
ROOT ANGLE	52°14'	29°36'
WHOLE DEPTH	0.719	
CHORDAL ADD	0.3409	0.3447
CHORD THICK	0.5233	0.5229


5.375
1.060
33° 41'
52° 48'
1/2
33° 41'
2 1/8
6.000
1.688
1.687
3
6.554
1/2 X 1/4
KEYWAY
MS
FAO
56° 19'
30°12'
1 3/4
56°19'
2 3/8
4.000
15/16
CI
1/2
1.277
1.938
1.937
3 5/8
9/16 X 5/16
KEYWAY
1 1/4
9.000
9.370

Assignment Sheet 2

Problems:

Note: You instructor may wish to assign an alternate problem.

A. Bevel gear—Draw gear only.

1. Number of teeth—20
2. Diametral pitch —5
3. Pressure angle—14 1/2° INV
4. Addendum—.20
5. Root angle—40°25′
6. Whole depth—.431
7. Chordal addendum—.204
8. Outside diameter—4.282
9. Pitch angle—48°
10. Pitch diameter—4″
11. Chordal thickness—.314
12. Backing—.707
13. Back angle—42°
14. Face—.9375
15. Face angle—53°03′
16. Keyway—3/16 × 3/32
17. Mounting distance—2.563
18. Hole size $\frac{.875}{.877}$ DIA
19. Hub size—1.5 DIA
20. Web thickness—.5625
21. Hub projection—.1875
22. Material—Cast iron

B. Complete the following cutting data table using the given information.

CUTTING DATA		
	Gear	Pinion
No. of Teeth	30	20
Diametral Pitch	5	
Pressure Angle	14 1/2°	
Whole Depth		
Root Angle		
Face Angle		
Chordal Thickness		
Addendum		

Power Transmission: Gears, Bearings, and Cams
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Assignment Sheet 3—Construct a Worm and Worm Gear Drawing

Name ________________________________ Overall Rating __________

Evaluation criteria	**Rating**
Worm drawing and completed data	______
Worm wheel drawing and completed data	______

Directions: On "B" size vellum or other media assigned by instructor, construct a worm gear. Include cutting data table and dimensions. On a second sheet of media, construct a worm. Use the following formulas to solve the incomplete cutting data in the problems.

A. Cutting data for worm:

1. Number of threads—n
2. Pitch—P
3. Pitch diameter—D = (2.4 × Pitch) + 1.1

   Note: This is a recommended value.

4. Lead and direction—Distance thread moves in one revolution, RH or LH

   Note: In a single thread, lead = pitch; in a double thread, lead = 2 pitch.

5. Lead angle—Tangent $\lambda = \dfrac{\text{Lead}}{\pi(\text{Pitch diameter})}$
6. Pressure angle—20° or 14 1/2°
7. Whole depth—W = .686 × Pitch
8. Outside diameter—OD = Pitch diameter + .636 × Pitch

Assignment Sheet 3

9. Face length—F = Pitch $\left(4.5 + \frac{\text{Number of teeth on gear}}{50}\right)$

B. Cutting data for worm wheel (gear):

1. Number of teeth = n
2. Pitch—P
3. Pitch diameter—D = Pitch $\left(\frac{\text{number of teeth}}{}\right)$
4. Addendum—a = 3,183 × Pitch
5. Whole depth—W = .686 × Pitch
6. Number of threads = t
7. Lead and direction—Distance thread moves in one turn; RH or LH
8. Lead angel—tangent $\lambda = \frac{\text{Lead}}{\pi(\text{Pitch diameter})}$
9. Pressure angel—20° or 14 1/2°
10. Throat diameter—TD = Pitch diameter + .636 × Pitch
11. Outside diameter—OD = Throat diameter + .4775 × Pitch
12. Face radius—R_F = 1/2 Pitch diameter of worm − .318 × Pitch
13. Rim radius—R_r = 1/2 Pitch diameter of worm + Pitch
14. Face width—F = 2.38 × Pitch + .25
15. Center distance—C = 1/2 (Pitch diameter of wheel + Pitch diameter of worm)

Problems:

Note: Your instructor may wish to assign an alternate problem.

A. Worm data—Complete data and draw.

1. Number of threads per inch—2
2. Pitch—.500

Assignment Sheet 3

3. Pressure angle—14 1/2°
4. Lead angle—7°53″
5. Right hand lead—1
6. Whole depth ______________________________
7. Addendum—.159
8. OD—2.618
9. Pitch diameter—2.3
10. Face length ______________________________

Note: Gear has 36 teeth.

B. Worm wheel data—Complete data and draw.

1. Number of teeth—36
2. Addendum—.159
3. Whole depth—.343
4. Number of threads—2
5. Pitch—.500
6. Pressure angle—14 1/2°
7. Lead angle — 7°53′
8. Right hand lead—1
9. OD—6.287
10. Throat diameter ______________________________
11. Pitch diameter ______________________________
12. Face radius—.99 R
13. Rim radius ______________________________
14. Hub width—2″

Assignment Sheet 3

15. Hub diameter—2.125
16. Hole in hub—$\begin{smallmatrix}1.004\\1.000\end{smallmatrix}$
17. Keyway—1 1/4 × 1/8
18. Web thickness—.5

Power Transmission: Gears, Bearings, and Cams
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Assignment Sheet 4—Calculate Gear Ratios

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Number of correct calculations in Problem A	______
Number of correct calculations in Problem B	______

Directions: Using the information sheet, calculate the gear ratio of the gears below and write the correct answers in blanks provided.

Problems:

A. Calculate gear ratio from information given.

1. Driven gear has 9 teeth
   Driving gear has 36 teeth

   What is the gear ratio: ____________________

2. Driven gear has 36 teeth
   Driving gear has 48 teeth

   What is the gear ratio: ____________________

3. Driven gear has 36 teeth
   Driving gear has 12 teeth

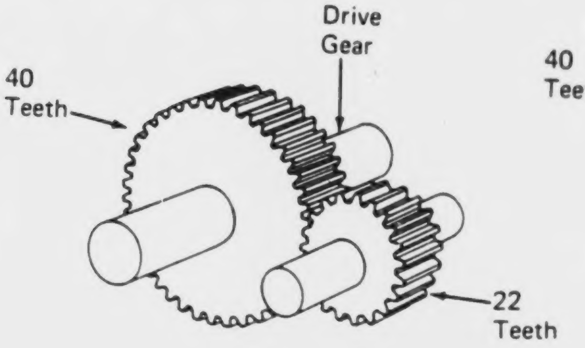
   What is the gear ratio: ____________________

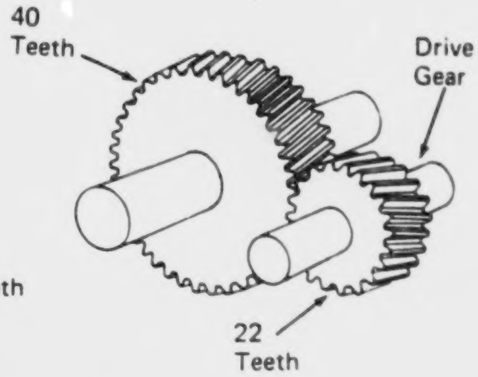
4. Driven gear has 50 teeth
   Driving gear has 50 teeth

   What is the gear ratio: ____________________

Assignment Sheet 4

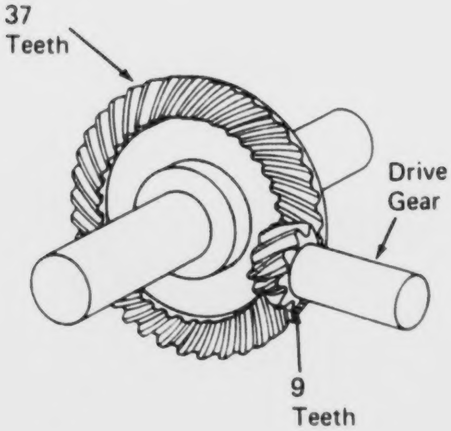
B. Calculate gear ratio from illustrations below.

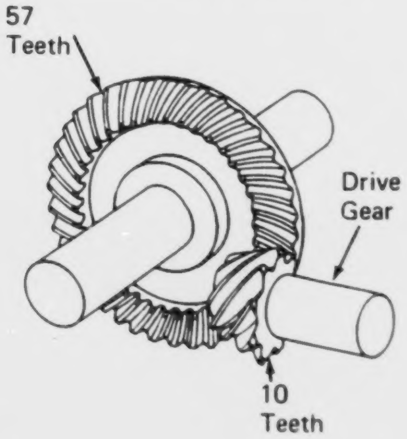

Drive Gear
40 Teeth
22 Teeth


40 Teeth
Drive Gear
22 Teeth

1. ______________________

2. ______________________

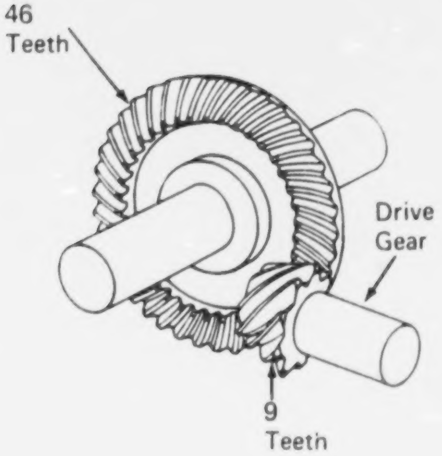

37 Teeth
Drive Gear
9 Teeth

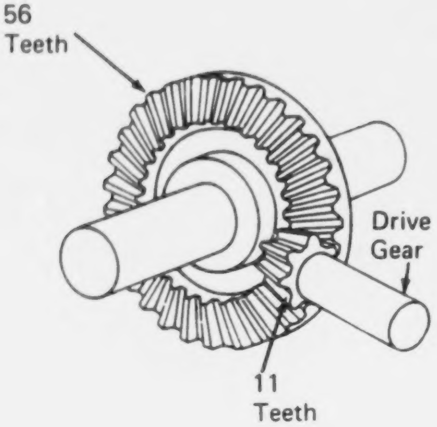

57 Teeth
Drive Gear
10 Teeth

3. ______________________

4. ______________________

Assignment Sheet 4


46
Teeth
Drive
Gear
9
Teeth


56
Teeth
Drive
Gear
11
Teeth

5. ______________________________

6. ______________________________

Power Transmission: Gears, Bearings, and Cams
Unit 11

Assignment Sheet 5—Determine Gear Rotation

Name ______________________________ Overall Rating __________

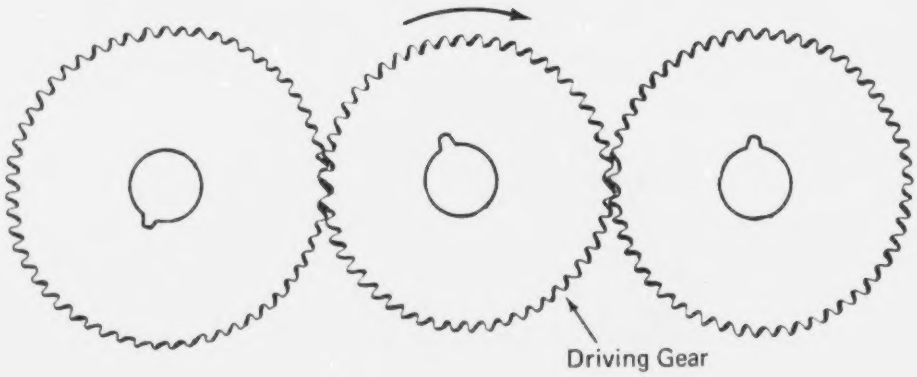
Evaluation criteria	**Rating**
Number of correct determinations in Problem A	_____
Number of correct determinations in Problem B	_____
Number of correct determinations in Problem C	_____

Directions: Calculate gear rotation by indicating with an arrow the direction in which the driven gears are turning.

CAD Alert: Use your CAD system and third-party software for constructing mating gears. Use the CAD program to indicate with arrows the direction of rotation.

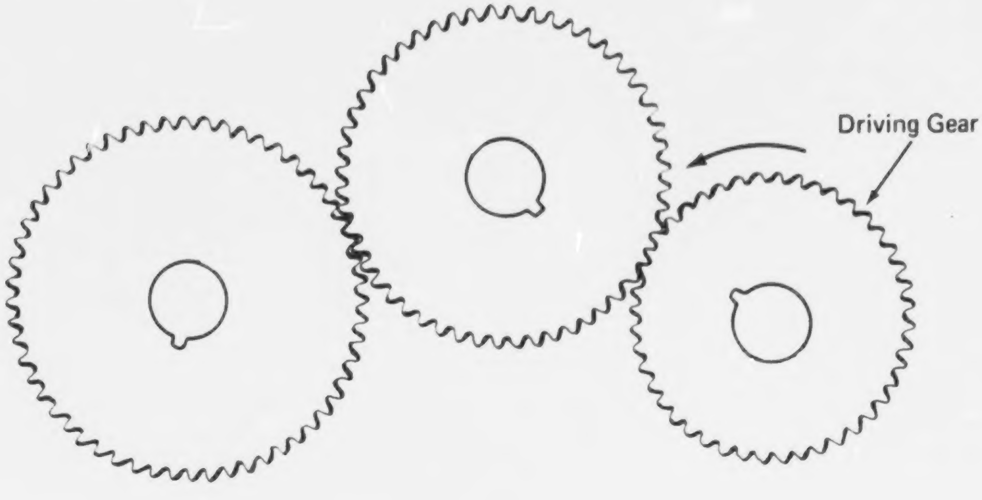
Problems:

A.

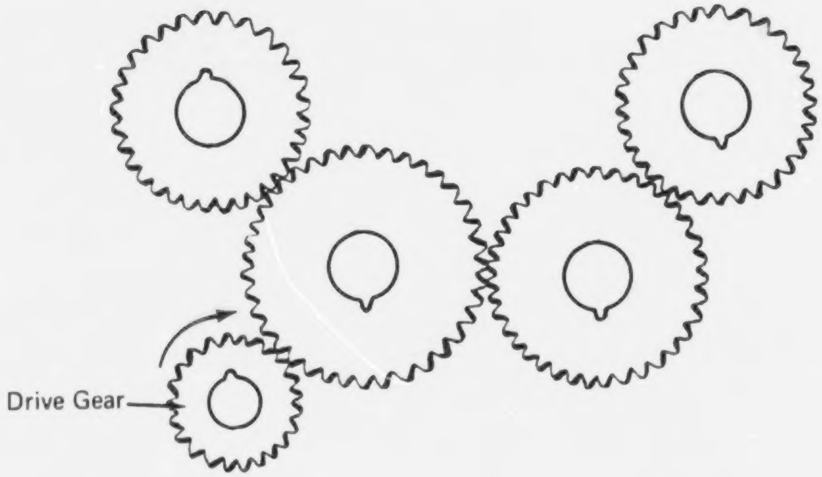


Assignment Sheet 5

B.


Driving Gear

C.



Power Transmission: Gears, Bearings, and Cams
Unit 11

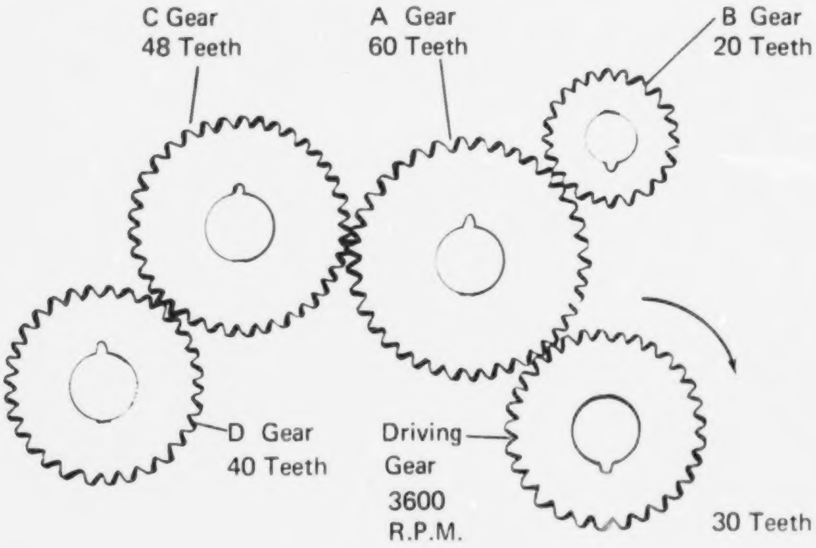
Assignment Sheet 6—Calculate Gear Ratios

Name ______________________________ Overall Rating __________

Evaluation criteria	Rating
Number of correct calculations in Problem A	______
Number of correct calculations in Problem B	______

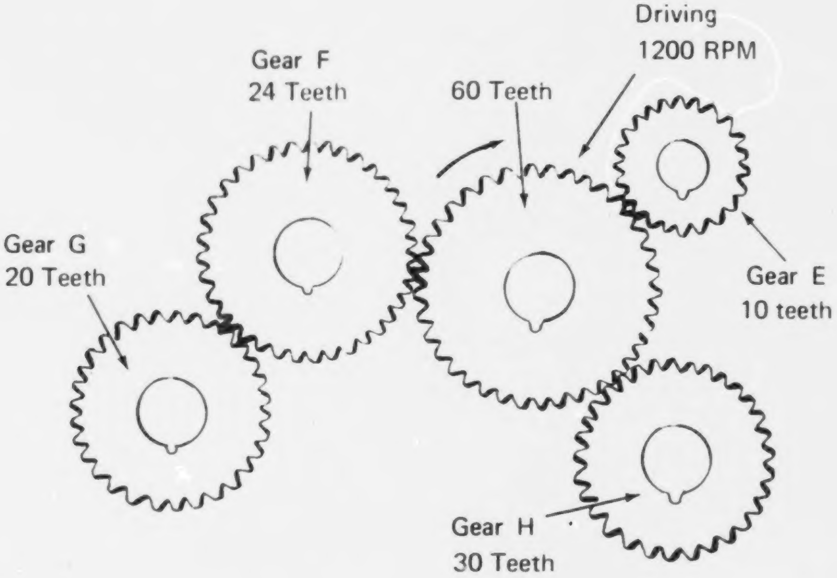
Directions: Calculate the direction of rotation, the gear ratio, and the RPM of each driven gear. Write answers in the blanks provided. For rotation, use C for clockwise and CC for counterclockwise.

	Rotation	Ratio	RPM
A. Gear A	________	________	________
B. Gear B	________	________	________
C. Gear C	________	________	________
D. Gear D	________	________	________


C Gear
48 Teeth
A Gear
60 Teeth
B Gear
20 Teeth
D Gear
40 Teeth
Driving Gear
3600
R.P.M.
30 Teeth

Assignment Sheet 6

		Rotation	Ratio	RPM
E.	Gear E			
F.	Gear F			
G.	Gear G			
H.	Gear H			


Driving
1200 RPM
Gear F
24 Teeth
60 Teeth
Gear G
20 Teeth
Gear E
10 teeth
Gear H
30 Teeth

Power Transmission: Gears, Bearings, and Cams
Unit 11

Assignment Sheet 7—Construct a Cam Drawing

Name ______________________________ Overall Rating __________

Evaluation criteria	Rating
Cam drawing profile and displacement diagram for Problem A	______
Cam drawing profile and displacement diagram for Problem B	______

Directions: On "B" size vellum or other media assigned by instructor, construct a cam drawing profile and displacement diagram for one of the following problems.

> **CAD Alert:** Use your CAD system and third-party software to construct the cam drawing profiles and the displacement diagrams.

Problems:

Note: Your instructor may wish to assign a different problem.

A. Cam:

1. Harmonic rise 0° through 90° to .75″
2. Dwell 90° through 180° through 360°
3. Harmonic drop 180° through 360°
4. Follower displacement 1.5″
5. Roller follower diameter .5″
6. Ream .875″ – 3/16 × 3/32 keyway
7. Thickness .50″

Assignment Sheet 7

B. Cam:

1. Parabolic rise 0° through 60° to 1.25″
2. Dwell 60° through 90°
3. Parabolic rise 90° through 150° to 2.00″
4. Harmonic drop 150° through 260° to 1.00″
5. Modified uniform motion 260° to 360°
6. Direction of rotation—Clockwise
7. Ream .625″ – 1/2 × 1/4 keyway
8. Thickness .50″

Power Transmission: Gears, Bearings, and Cams
Unit 11

Assignment Sheet 8—Select Types of Bearings From Handbooks

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Proper use of examples to make selections	______
Proper selections made in Problems A and B	______

Directions: Select types of bearings for the following problems using available bearing handbooks and the table included at the end of this assignment sheet. An example is given to be used as a guideline for solving the problems. The following is a list of general considerations for selecting bearings.

1. Choose roller bearings for larger sizes and heavier loads because they are less expensive than ball bearings.
2. Choose ball bearings for smaller sizes and lighter loads because they are less expensive than roller bearings.
3. Under shock or impact loading, roller bearings are more satisfactory than ball bearings.
4. Use a self-aligning or spherical roller bearing when there is misalignment between housing and shaft.
5. Ball thrust bearings should be used for pure thrust loads only.
6. Use a deep groove or angular contact ball bearing for high speeds of pure thrust loads.
7. For long operating periods without attention, the deep groove ball bearing is available with seals built into the bearings.

Example problem: Select a light inch ball bearing from a handbook that would satisfy the following design needs:

1. Maximum speed = 5800 RPM

Assignment Sheet 8

2. Dynamic load rating = 3400 lbs.

3. Static load rating = 1800 lbs.

What is the bore size and outside diameter size?

Note: Experience has shown that actual failure of ball bearings has been due to fatigue. Calculation of rating life, basic load rating, and other factors will be found in a machine design class.

Example solution:

1. Locate light inch ball bearings from mechanical components handbook or Table 1.
2. Read down the limiting speed column for 5800 RPM; notice it falls between 5600 and 6300.
3. Choose 6300 RPM which is LS 13 1/2.
4. Read down the dynamic load rating column for 3400 lbs.; notice it falls between 3350 and 4050 lbs.
5. Choose 4050 lbs. which is LS 12.
6. Read down the static load rating column for 1800 lbs. which is LS 10.
7. Decide which bearing will satisfy the extreme condition and yet satisfy the other conditions.
    a. Choose the largest load either dynamic or static as the controlling factor.
    b. The LS 12 bearing number at 4050 lbs. dynamic load is chosen.
    c. The 1800 lb. static load is within the static load rating of 2750 lbs.
    d. The limiting speed of 8000 RPM covers the 5800 RPM expected speed.
8. Bore size is 1 1/4"; outside diameter is 2 3/4".

Assignment Sheet 8

Problems:

A. Select a light inch ball bearing from a handbook that would satisfy the following design needs:

1. Maximum speed = 3400 RPM
2. Dynamic load rating = 7500 lbs.
3. Static load rating = 9150 lbs.

What is the bore size and outside diameter size? ____________________

B. Select a light inch ball bearing from a handbook that would satisfy the following design needs:

1. Maximum speed = 2200 RPM
2. Dynamic load rating = 4800 lbs.
3. Static load rating = 1375 lbs.

What is the bore size and outside diameter size? ____________________

Assignment Sheet 8

Table 1
Light Inch Ball Bearings

BEARING NUMBER*	BOUNDARY DIMENSIONS inch			MAX. FILLET RADIUS Shaft & Housing	APPROX. WEIGHT	S_L LIMITING SPEED ‡	C DYNAMIC LOAD RATING	C_o STATIC LOAD RATING
Norma FAG	BORE	O. DIAM	WIDTH	inch	lb.	rpm	lb.	lb.
LS 5	½	1 5/16	⅜	.020	.12	22000	1180	695
LS 7	⅝	1 9/16	7/16	.020	.15	16000	1660	1000
LS 8	¾	1⅞	9/16	.040	.27	14000	2200	1370
LS 9	⅞	2	9/16	.040	.32	12000	2240	1370
LS 10	1	2¼	⅝	.040	.42	11000	2800	1800
LS 11	1⅛	2½	⅝	.040	.51	9000	3350	2240
LS 12	1¼	2¾	11/16	.040	.63	8000	4050	2750
LS 12½	1⅜	3	11/16	.040	.86	7100	4400	3100
LS 13	1½	3¼	¾	.060	1.10	7100	5500	3800
LS 13½	1⅝	3½	¾	.060	1.29	6300	5600	4000
LS 14	1¾	3¾	13/16	.060	1.61	5600	6300	4650
LS 14½	1⅞	4	13/16	.060	1.85	5600	7500	5600
LS 15	2	4	13/16	.060	1.78	5600	7500	5600
LS 16	2¼	4½	⅞	.060	2.40	5000	9150	6950
LS 17	2½	5	15/16	.060	3.15	4500	10800	8500
LS 18	2¾	5¼	15/16	.060	3.40	4000	11400	9150
LS 19	3	5¾	1 1/16	.060	4.65	3600	12500	9800
LS 19½	3¼	6	1 1/16	.060	4.90	3600	14300	11800
LS 20	3½	6½	1⅛	.080	6.20	3200	16000	13200
LS 20½	3¾	6¾	1⅛	.080	6.70	3200	18600	15600
LS 21	4	7¼	1¼	.080	8.80	2800	19600	17600
LS 21½	4¼	7½	1¼	.080	9.15	2800	22800	20000
LS 22	4½	8	1 5/16	.080	11.20	2500	24500	22400
LS 22½	4¾	8¼	1 5/16	.080	11.40	2500	25000	22800
LS 23	5	9	1⅜	.080	15.00	2200	26500	24500
LS 23½	5½	9½	1⅜	.080	15.60	2200	28000	27000
LS 24	6	10½	1 9/16	.10	22.60	2000	32000	32500
LS 24½	6½	11	1 9/16	.10	24.00	1800	33500	35500
LS 25	7	12	1¾	.10	36.50	1800	35500	39000
LS 25½	7½	12½	1¾	.10	46.00	1600	35500	39000
LS 26	8	13	1¾	.10	57.00	1600	36500	42500

Courtesy of FAG Bearings Corporation

Layouts and Working Drawings
Unit 12

Objective Sheet

Unit Objective

After completing this unit, the student should be able to draw a design layout, a set of detail drawings, and an assembly drawing. The student should also be able to complete a parts list, a detailed title block and revision block, and make a drawing revision. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to layouts and working drawings with their correct definitions.
2. Differentiate between standard and additional information on a title form.
3. Identify information on a revision block.
4. List information on a bill of materials/parts list.
5. Arrange in order the stages in the design process.
6. Select true statements about design layouts and their characteristics.
7. Select true statements about the basic elements of a design layout sketch.
8. Match standard parts of a detail drawing with their functions.
9. Match parts of an assembly drawing with their functions.
10. Complete statements about information on outline or installation assembly drawings.

Objective Sheet

11. Select information on weldment assembly drawings.
12. Match parts of forging drawings with their characteristics.
13. Match parts of a pattern or casting drawing with their characteristics.
14. Draw a design layout. (Assignment Sheet 1)
15. Draw a set of detail drawings. (Assignment Sheet 2)
16. Draw an assembly drawing. (Assignment Sheet 3)
17. Complete a detailed title block and revision block. (Assignment Sheet 4)
18. Complete a parts list. (Assignment Sheet 5)
19. Make a drawing revision. (Assignment Sheet 6)

Layouts and Working Drawings
Unit 12

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.

2. Review Teaching Suggestions section that follows. Plan for classroom activities.

3. Plan for enrichment of exceptional students as well as accommodation of special needs students.

4. Make transparencies from the transparency masters included with this unit. These appear in the teacher edition only and are designed to be used with the following objectives:

   TM 1—Engineering Change Notice (Objective 1)
   TM 2—Design Layout (Objective 7)
   TM 3—Detail Drawing (Objective 8)
   TM 4—Assembly Drawing (Objective 9)
   TM 5—Detail Assembly Drawing (Objective 9)
   TM 6—Outline or Installation Assembly (Objective 10)
   TM 7—Weldment Assembly Drawing (Objective 11)
   TM 8—Forging Drawing (Objective 12)
   TM 9—Casting Drawing (Objective 13)

5. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.

6. Develop teaching plan. Adjust for different learning styles.

Delivery and Application

7. Make copies of Unit Evaluation Form.

8. Provide students with unit of instruction.

9. Discuss unit and specific objectives.

10. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.

11. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Suggested Activities

Evaluation

12. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.

13. Make copies of the written test. Add or modify test questions as needed.

14. Give written test.

15. Compile assignment sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignments.

16. Reteach and retest as required.

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Check industries in your area for firms that uses detail drawings and assembly drawings in their production process. Invite an engineer or technician to talk to the class about the importance of correct drawings for successful production. Skill areas: **Foundation skills, listening**.

2. When you talk about assembly drawings in Objective 9, have samples of good assembly drawings available for students to examine. Assign groups of students to certain drawings, and have the groups report their ideas about the quality of the assembly drawing and how much of it they can interpret. Skill areas: **Group effectiveness skills, teamwork**.

3. Review all of the assignment sheets, and point out the ones where the **CAD Alert** box appears. Use these assignment sheets to encourage students to continue learning how to effectively work at a CAD station. Skill areas: **Learning skills, learning to learn**.

4. Make copies of the Engineering Change Notice in TM 1. Take student drawings from any of the early assignment sheets and prepare a formal ECN for each student if you have the time. Use it as extra credit for Assignment Sheet 6. Skill areas: **Foundation skills, writing**.

Suggested Activities

Resources Used in Developing This Unit

1. American National Standards Institute. *B6.13-1965 (R1974); B6.1-1978 (R1947); B6.7-1967 (R1974); Y14.7.1* and *Y14.7.2-1971*. New York: The American Society of Mechanical Engineers, various years.

2. French, Thomas E., et. al. *Mechanical Drawing CAD—Communications*, 11th ed. New York: Gregg Division McGraw Hill Publishing Co., 1990.

3. Giesecke, Frederick E. *Technical Drawing*. New York: Macmillan Publishing Company, Inc., 1992.

4. Goetsch, David L., and John A. Nelson and William S. Chalk. *Technical Drawing Fundamentals.CAD.Design*. Albany, NY: Delmar Publishers, Inc., 1989.

Layouts and Working Drawings
Unit 12

Answers to Assignment Sheets

All assignment sheets should be evaluated according to criteria written in the assignment sheets themselves. Evaluation for CAD-generated materials should note advanced performance.

Layouts and Working Drawings
Unit 12

Answers to Written Test

1.
   a. 7
   b. 4
   c. 9
   d. 6
   e. 12
   f. 1
   g. 13
   h. 3
   i. 8
   j. 5
   k. 2
   l. 11
   m. 10

2.
   a. A
   b. S
   c. S
   d. A
   e. A
   f. S

3.
   a. Zone for location of change
   b. Letter of change
   c. Date of change
   d. Person checking or approving change

4.
   a. Any two of the following in any order:

      (1) Item referring to the assembly drawing
      (2) Part name
      (3) Number required
      (4) Material from which part is made

   b. Any four of the following in any order:

      (1) Stock number
      (2) Description or nomenclature
      (3) Address of vender
      (4) Unit of measure
      (5) Group assembly where used
      (6) Approval
      (7) Release date
      (8) Originator
      (9) Revision
      (10) Stock size
      (11) Pattern number
      (12) Weight

Answers to Written Test

5. a. 3
   b. 5
   c. 1
   d. 4
   e. 2

6. a, c

7. b, c, d, f, g

8. a. 3
   b. 1
   c. 2

9. a. 2
   b. 6
   c. 1
   d. 5
   e. 3

10. a. Structure
    b. External
    c. Subassemblies

11. a, b, c, e, f

12. a. 2
    b. 1
    c. 3

13. a. 1
    b. 2

14. a. A
    b. P
    c. A or P
    d. A
    e. P

15. a. Pitch circle
    b. Base circle
    c. Follower
    d. Pressure angle

Layouts and Working Drawings
Unit 12

Written Test

Name ______________________________ Date __________________ Score ____________

1. Match the terms on the right with their correct definitions.

______a. A drawing showing all parts in their working position

______b. An itemized list of parts shown with an assembly drawing

______c. A detail drawing of a workpiece to be cast

______d. An accurate drawing of all parts in working positions showing clearances of moving parts, ease of assembly, and ease of serviceability

______e. An organized method to combine scientific principles, standard parts, and resources into the solution of a problem

______f. A combined detail and assembly drawing used when the details are simple enough for all parts to be shown and dimensioned clearly while shown in assembled positions

______g. A drawing containing the necessary information to completely manufacture a single part or one stage of a single part

______h. An approved change to a drawing caused by a change in design, tool changes, errors in design or production, or customer changes

______i. A detail drawing of a workpiece to be forged in dies

______j. A change made on a drawing

1. Detail assembly drawing
2. Title
3. Engineering change notice
4. Bill of materials/parts list
5. Revision
6. Design layout
7. Assembly drawing
8. Forging drawing
9. Casting drawing
10. Zoning
11. Title form
12. Design process
13. Detail drawing

Written Test

______k. The name of an object or a project

______l. A standardized place to show all information not shown with notes and dimensions on a drawing

______m. Equal intervals along the margins labeled with numbers along the horizontal margin and with letters along the vertical margin for locating an area on a drawing

2. Differentiate between standard and additional information on a title form. Place an "S" in the blanks beside standard information and an "A" in the blanks beside additional information.

______a. Tolerances

______b. Revision letter

______c. Signature of drafter with date of completion

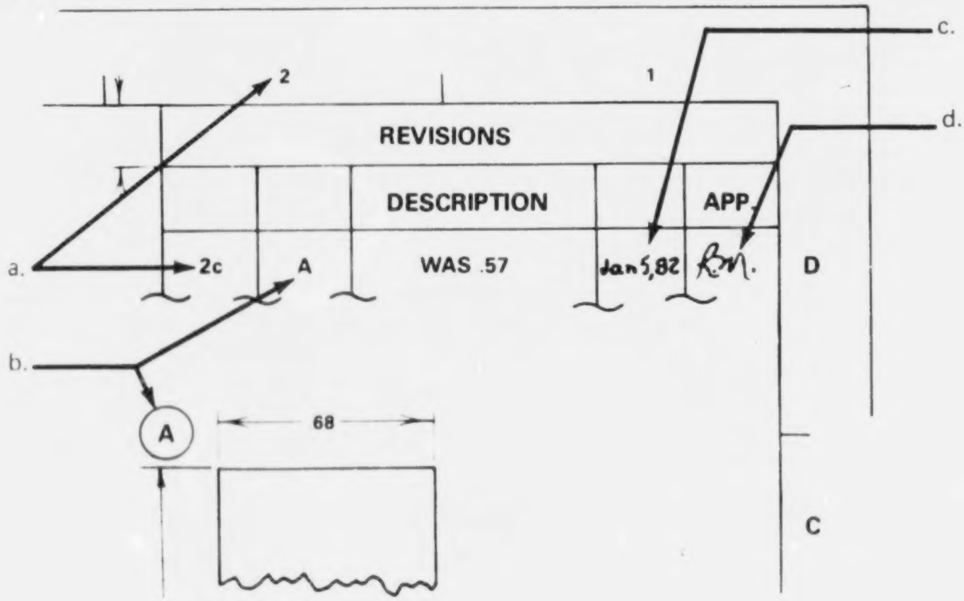
______d. Hardness

______e. Heat treatment

______f. Predominate scale of drawing

Written Test

3. Identify information on a revision block. Insert the proper item in each of the blanks provided.


2
1
c.
REVISIONS
d.
DESCRIPTION
APP.
a.
2c
A
WAS .57
Jan 5,82
R.M.
D
b.
A
68
C

a. ______________________ b. ______________________

c. ______________________ d. ______________________

4. List information on a bill of materials/parts list. Complete each part of the following:

   a. Standard information

      (1) ______________________

      (2) ______________________

   b. Additional information

      (1) ______________________

      (2) ______________________

      (3) ______________________

      (4) ______________________

Written Test

5. Arrange in order the stages in the design process. Place a "1" in the blank beside the first stage, and number the remaining stages in order.

______a. Refinement of solutions

______b. Presentation/working drawings

______c. Problem identification

______d. Model, prototype, or CAD analysis

______e. Preliminary ideas and concepts

6. Select true statements about design layouts and their characteristics. Place an "X" beside each true statement.

______a. Design layouts are drawn by a designer as part of the design process.

______b. The degree of detail needed on a layout depends entirely on the nature of the layout.

______c. The layout must be drawn accurately with thin lines on CAD or board.

______d. Layouts usually include all dimensions.

7. Select true statements about basic elements of a design layout sketch. Place an "X" beside each true statement.

______a. Design layout sketches do have to be drawn accurately to prove that something works.

______b. A designer or engineer will simply sketch a layout and leave it to a drafter to make the detail drawing.

______c. Otherwise, layout sketches should include all vital information including projection, multiview or isometric, and proper line symbols and darkness.

______d. Calculations should be made as needed for strength, function, cost, and weight.

______e. Recommend standard parts only when other parts aren't available, and include notes for them along with notes for special processes or anticipated manufacturing problems.

______f. Include proportion information and shape or form dimensions along with all critical dimensions.

______g. Include ease of assembly and ease of serviceability.

Written Test

8. Match standard parts of a detail drawing with their functions. Place the number of the detail part in the blank beside the description of its function.

______a. Includes multiview, auxiliary, sections, and /or pictorials

______b. Includes size, location, and tolerances

______c. May be general or specific to include materials, processes, or other specifications

1. Dimensions
2. Notes
3. Shape description

9. Match parts of an assembly drawing with their functions. Place the number of the part name in the blank beside its description.

______a. Show the relationship of parts, not the shapes of individual parts

______b. Show the inside function or construction of parts

______c. Used only to promote clarity, but unnecessary when several sections are used; might actually confuse the reading of the drawing

______d. Show maximum or minimum sizes or locations of machine parts after assembly and overall size; only certain dimensions and notes are given

______e. Allow for quick identification of physical shape, and guide reader to the parts list

1. Hidden lines
2. Views
3. Parts identification numbers
4. Views
5. Dimensions
6. Sections

10. Complete statements about information on outline or installation assembly drawings. Circle the material that best completes each of the following statements.

a. Assemblies present the method for installing or erecting a machine or (**part**) (**structure**).

b. Assemblies outline and show relationships of (**inside**) (**external**) surfaces.

c. Assemblies show relationship of final positioning for (**tolerancing**) (**subassemblies**).

Written Test

11. Select information on weldment assembly drawings. Place an "X" beside each item that qualifies as such information.

______a. Part identification

______b. Dimensioning, including the detailed or after-welding final dimensions; proper jigs must be used to prevent distortion and maintain final dimensions

______c. Standard welding symbols

______d. Threaded fasteners

______e. Draft

______f. Multiviews and auxiliary views, if used, but sections are normally not used

12. Match parts of forging drawings with their characteristics. Place the number of the forging part in the blank beside the definition of its characteristic.

______a	Minimum sizes	1. Parting line
______b.	Separation of upper and lower dies	2. Fillets and rounds
______c.	Ease in removal from dies	3. Draft

13. Match parts of a pattern or casting drawing with their characteristics. Place the number beside the part name in the blank beside the description of its characteristic.

______a.	Minimum sizes	1. Fillets and rounds
______b.	Separation of one mold from the other	2. Partling line

***Permission to duplicate this test is granted.**

Layouts and Working Drawings
Unit 12

Unit Evaluation Form

Student Name ______________________ Unit Rating ________

Assignment Sheet 1—Draw a Design Layout Rating ______

Comments: ______________________________________

____

Assignment Sheet 2—Draw a Set of Detail Drawings Rating ______

Comments: ______________________________________

____

Assignment Sheet 3—Draw an Assembly Drawing Rating ______

Comments: ______________________________________

____

Assignment Sheet 4—Complete a Detailed Title Block and Revision Block Rating ______

Comments: ______________________________________

____

Assignment Sheet 5—Complete a Parts List Rating ______

Comments: ______________________________________

____

Assignment Sheet 6—Make a Drawing Revision Rating ______

Comments: ______________________________________

____

Unit Evaluation Form

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ____

____

Teacher Signature ______________________ Date __________

Student Signature ______________________ Date __________

Permission to duplicate this form is granted.

739

Engineering Change Notice

NO. AN

DATE ISSUED | CONT ON SHEET | SHEET NO

APPARATUS.

SERIES AN NO ☐ YES ☐ FINAL ☐

AR NO. | REQ

ENG PROD PLAN AFFECTED ☐ NOT AFFECTED ☐ | PREVIOUS SERIES AN | CLASS OF CHG. 1 EMERGENCY 2 MEET SPEC. 3 EXC'D SPEC 4 NEW MODEL

IT.	NAME OF PART	DWG NO.	REV	UNITS AFFECTED	SERIAL NOS

REASON FOR CHANGE/PROBLEM

SUMMARY OF CHANGE/SOLUTION

STATUS OF MATERIAL

TMBS		MDBS		RTBS	

SERIAL NUMBERS TO BE REWORKED

PROGRAMMING AFFECTED NO ☐ YES ☐ | DIAGNOSTICS AFFECTED NO ☐ YES ☐ PGMS

PRODUCT SERVICE INFORMATION

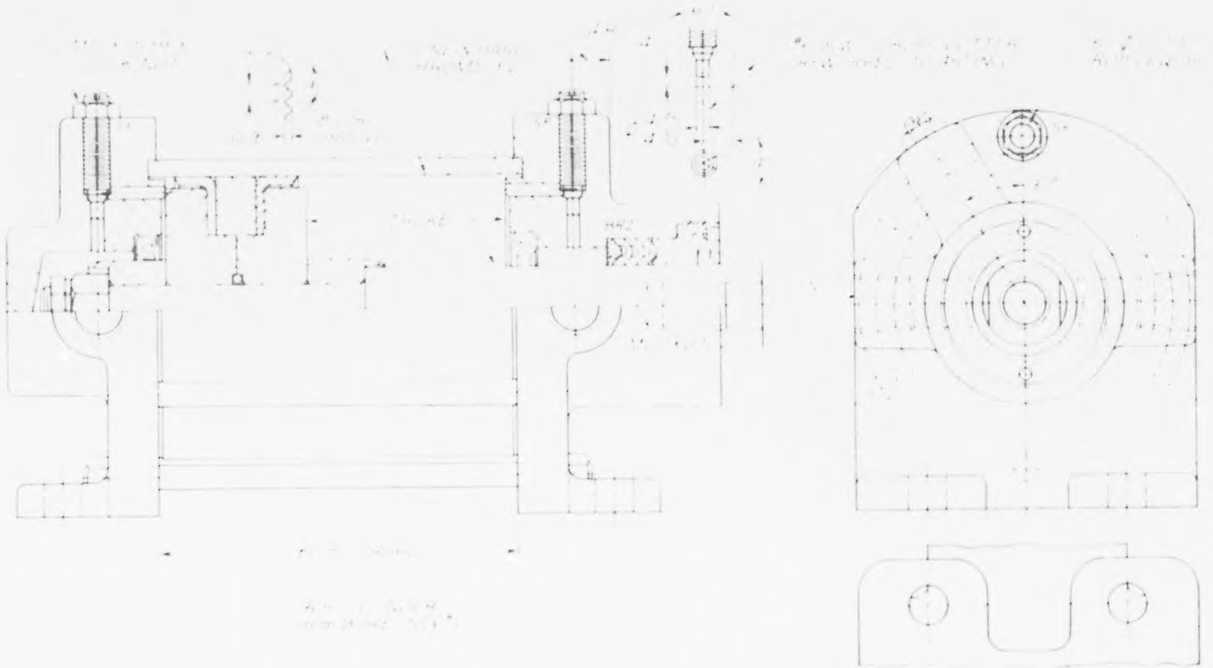
DOCUMENTATION IS AFFECTED ☐ NOT AFFECTED ☐

EQUIP CHANGE IS MANDATORY ☐ NOT AFFECTED ☐

SPARE PARTS ARE AFFECTED ☐ NOT AFFECTED ☐

ISSUED BY:	DATE:	APPROVALS:	DIST KEY		
APPROVED BY:	DATE:				

Design Layout



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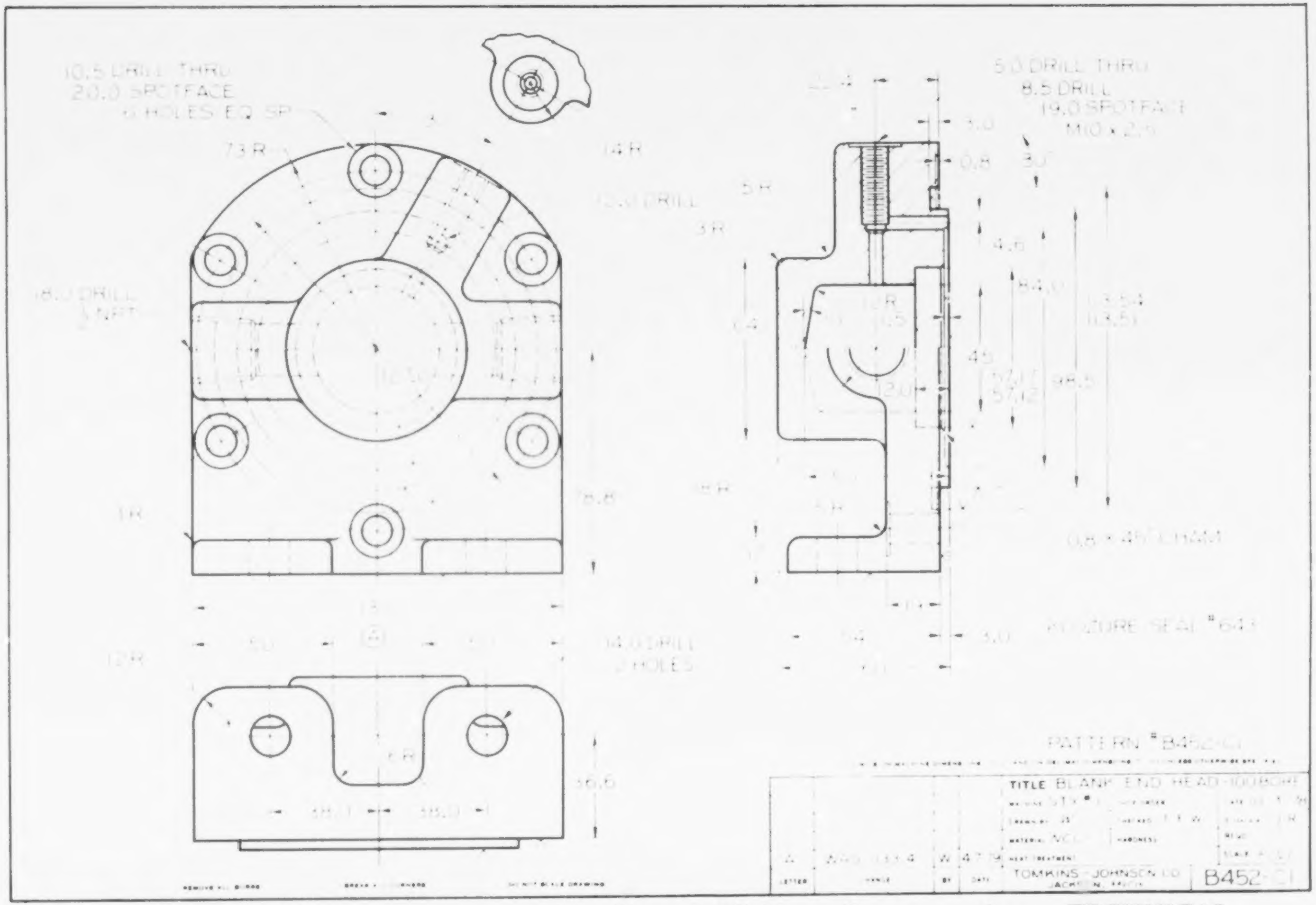
Detail Drawing


10.5 DRILL THRU
20.0 SPOTFACE
6 HOLES EQ SP
73 R
14 R
12.0 DRILL
5 R
3 R
18.0 DRILL
5.0 DRILL THRU
8.5 DRILL
19.0 SPOTFACE
M10 x 2.5
3.0
0.8
4.6
84.0
45
12R
12.0
98.5
78.8
0.8 x 45° CHAM
14.0 DRILL
2 HOLES
12 R
6 R
38.0
36.6
PATTERN #B452-CI
TITLE BLANK END HEAD-100 BORE
TOMKINS-JOHNSON CO
JACKSON, MICH.
B452-CI

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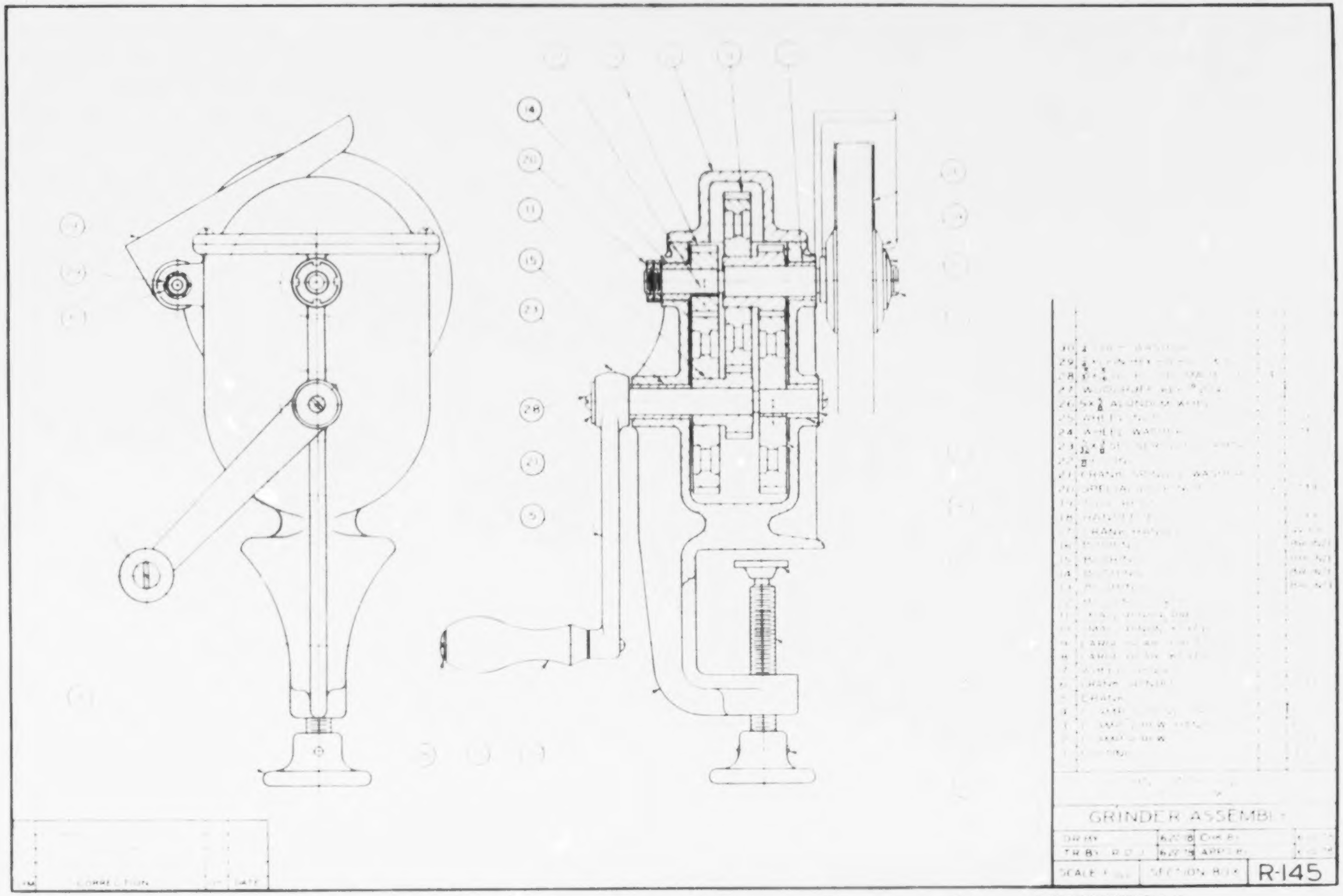
Mechanical Drafting With CAD, Unit 12
Teacher Page 21

TM 3

743

7.4.4

Assembly Drawing



30
29
28
27
26 5×⅝ ALUNDUM WHEEL
25
24 WHEEL WASHER
23
22
21 CRANK SPINDLE WASHER
20 SPECIAL
19
18 HANDLE
17 CRANK HANDLE
16 BUSHING
15 BUSHING
14 BUSHING
13 BUSHING
6 CRANK SPINDLE
5 CRANK
2 CLAMP SCREW
CORRECTION
DATE
GRINDER ASSEMBLY
DR BY
TR BY
CH'K BY
APP'D BY
SCALE
SECTION
R-145

Mechanical Drafting With CAD Unit 12
Teacher Page 23

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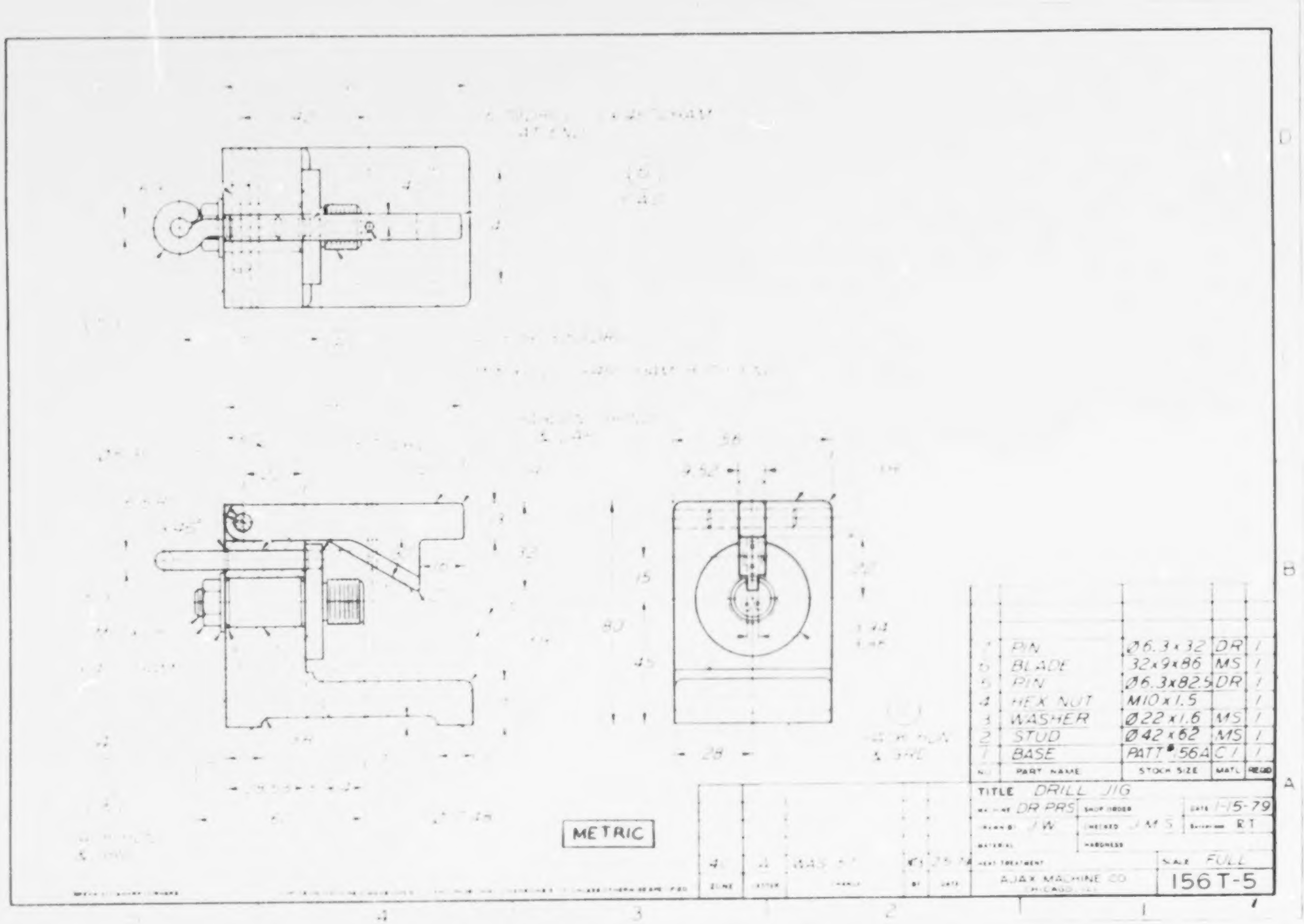
Detail Assembly Drawing


METRIC
7 PIN Ø6.3×32 DR 1
6 BLADE 32×9×86 MS 1
5 PIN Ø6.3×82.5 DR 1
4 HEX NUT M10×1.5 1
3 WASHER Ø22×1.6 MS 1
2 STUD Ø42×62 MS 1
1 BASE PATT #156A C I 1
NO PART NAME STOCK SIZE MATL REQD
TITLE DRILL JIG
DR PRS
DATE 1-15-79
J W
CHECKED J M S
R T
SCALE FULL
AJAX MACHINE CO
CHICAGO
156T-5

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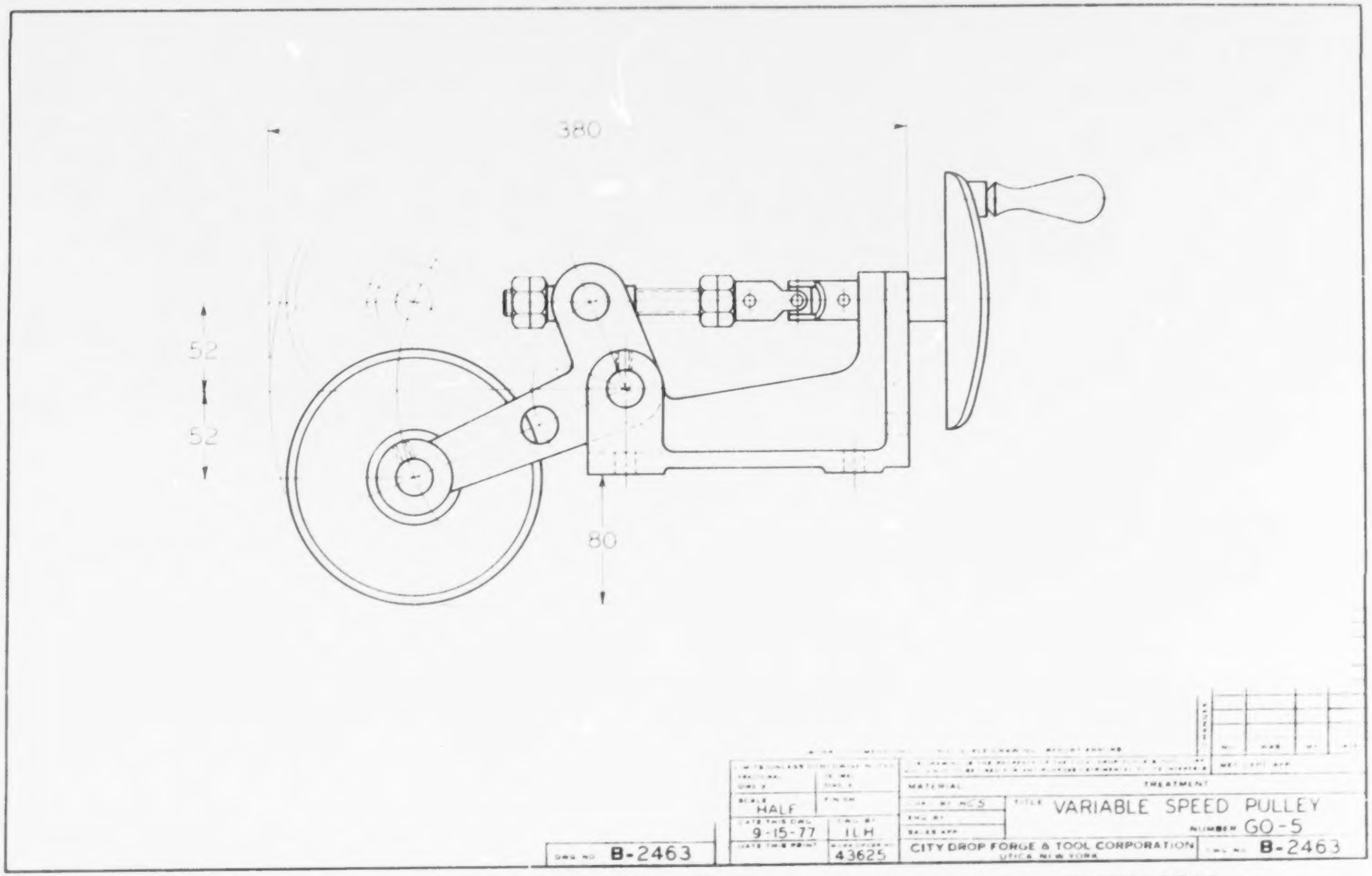
Outline or Installation Assembly


380
52
52
80
DWG NO B-2463
SCALE HALF
DATE THIS DWG 9-15-77
DWN BY ILH
43625
MATERIAL
TREATMENT
TITLE VARIABLE SPEED PULLEY
NUMBER GO-5
CITY DROP FORGE & TOOL CORPORATION
UTICA NEW YORK
DWG NO B-2463

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Mechanical Drafting With CAD, Unit 12
Teacher Page 27

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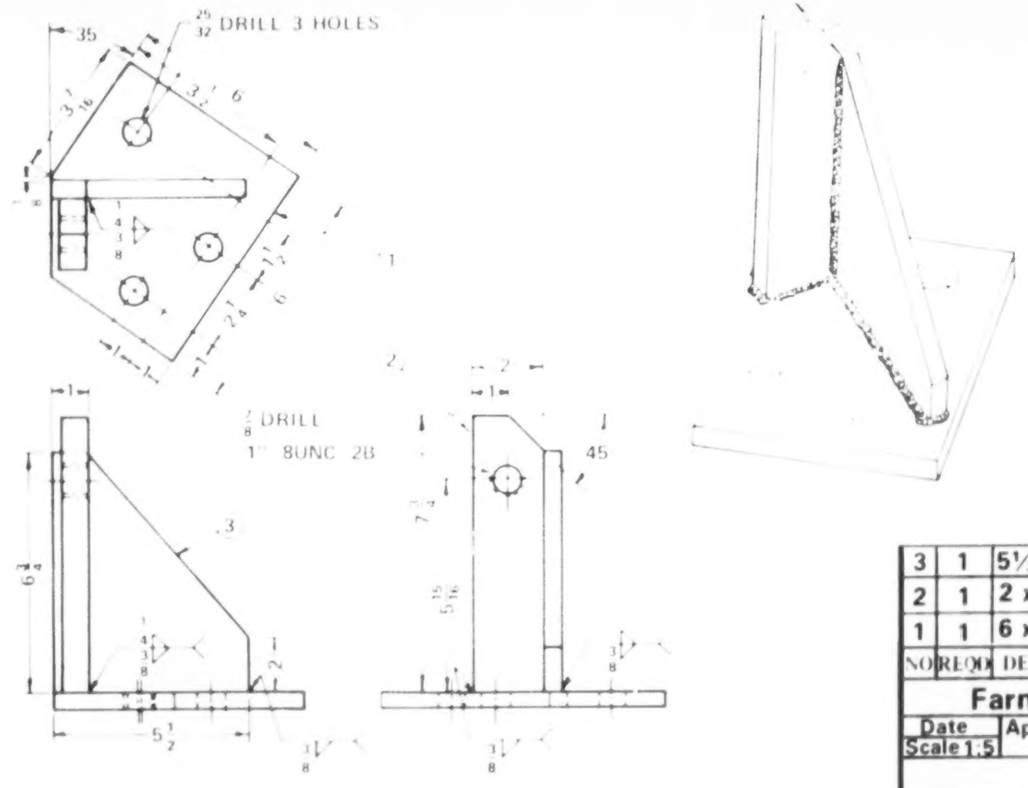
Welding Assembly Drawing



35
25/32 DRILL 3 HOLES
3 1/16
3 1/2
6
1/8
1/4
3/8
1
1 1/2
2 1/4
6
2
5/8 DRILL
1"-8UNC 2B
3
6 3/4
5 1/2
2
1
7 3/4
5 15/16
45
3/8

3	1	5½ x ½ Plate 6¾ long	1020
2	1	2 x ¾ Bar - 7¾ long	1020
1	1	6 x ½ Plate - 6 long	1020
NO	REQD	DESCRIPTION	QTY

Farm Machines Inc.

Date	Approved By	Dr By
Scale 1:5		Ck By

Bracket Assembly	15B625

Mechanical Drafting With CAD Unit 12
Teacher Page 29

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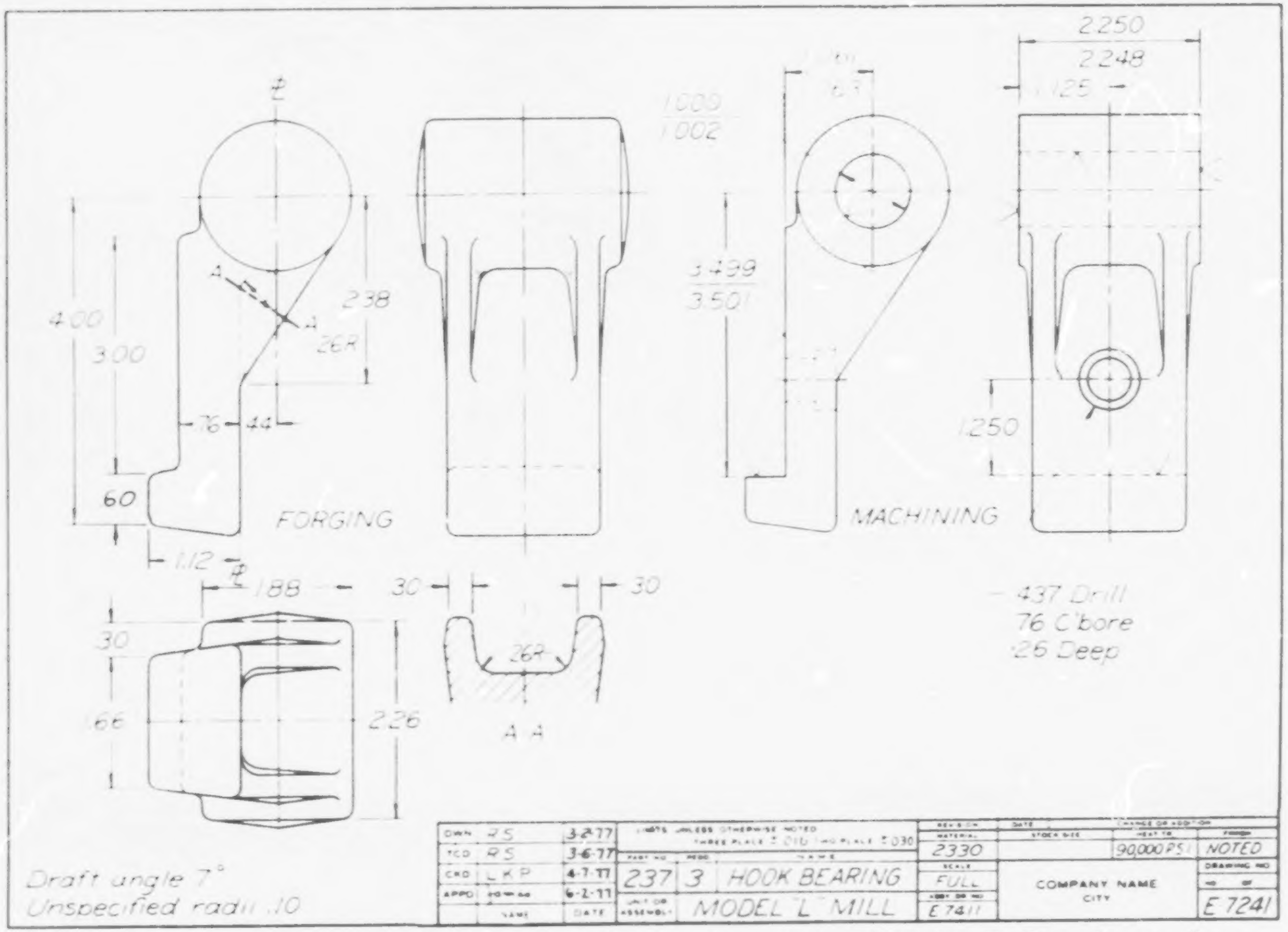
Forging Drawing


2.250
2.248
1.125
1.009
1.002
3.499
3.501
1.250
4.00
3.00
2.38
.26R
.76
.44
.60
1.12
1.88
.30
.30
.30
1.66
2.26
.26R
A
A
A-A
FORGING
MACHINING
.437 Drill
.76 C'bore
.26 Deep
Draft angle 7°
Unspecified radii .10
DWN RS 3-2-77
TCD RS 3-6-77
CKD LKP 4-7-77
APPD 6-2-77
NAME
DATE
LIMITS UNLESS OTHERWISE NOTED
THREE PLACE ±.010 TWO PLACE ±.030
PART NO
REQD
NAME
237
3
HOOK BEARING
UNIT OR ASSEMBLY
MODEL "L" MILL
REVISION
DATE
CHANGE OR ADDITION
MATERIAL
2330
STOCK SIZE
HEAT TR
90,000 PSI
FINISH
NOTED
SCALE
FULL
ASSY DR NO
E 7411
COMPANY NAME
CITY
DRAWING NO
NO OF
E 7241

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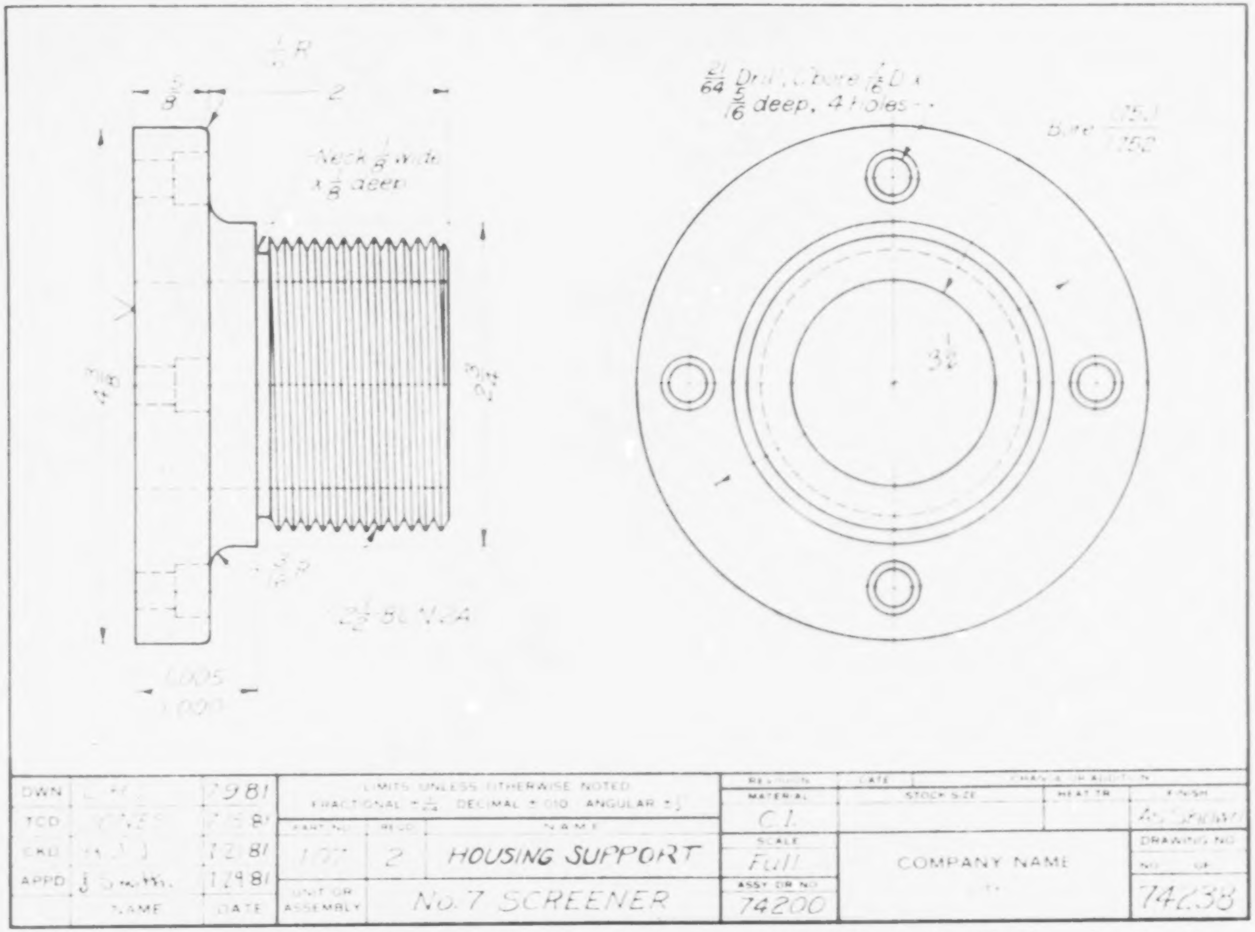
Casting Drawing


$\frac{1}{8}$R
$\frac{5}{8}$
2
Neck $\frac{1}{8}$ wide
x $\frac{1}{8}$ deep
$4\frac{3}{8}$
$2\frac{3}{4}$
$\frac{3}{16}$R
$2\frac{1}{2}$-8UNC-2A
1.005
1.000
$\frac{21}{64}$ Drill, Cbore $\frac{1}{16}$D x
$\frac{5}{16}$ deep, 4 Holes
Bore 1.251
1.250
$3\frac{1}{2}$
DWN
TCD
CKD
APPD J Smith
NAME
7 9 81
7 15 81
7 21 81
7 29 81
DATE
LIMITS UNLESS OTHERWISE NOTED
FRACTIONAL ± $\frac{1}{64}$ DECIMAL ± .010 ANGULAR ± $\frac{1}{2}$°
PART NO
REQD
NAME
2
HOUSING SUPPORT
UNIT OR ASSEMBLY
No. 7 SCREENER
REVISION
DATE
CHANGE OR ADDITION
MATERIAL
C.I.
STOCK SIZE
HEAT TR
FINISH
As Shown
SCALE
Full
ASSY DR NO
74200
COMPANY NAME
DRAWING NO
NO. OF
74238

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Layouts and Working Drawings
Unit 12

Information Sheet

1. Terms and definitions

   a. **Assembly drawing** — A drawing showing all parts in their working position

   b. **Bill of materials/parts list** — An itemized list of parts shown with an assembly drawing

   c. **Casting drawing** — A detail drawing of a workpiece to be cast

   d. **Design layout** — An accurate drawing of all parts in working positions showing clearances of moving parts, ease of assembly, and ease of serviceability

   e. **Design process** — An organized method to combine scientific principles, standard parts, and resources into the solution of a problem

   f. **Detail assembly drawing** — A combined detail and assembly drawing used when the details are simple enough for all parts to be shown and dimensioned clearly while shown in assembled positions

   Note: The detail assembly drawing is used on aircraft subassemblies, drawings of jigs and fixtures, and on welding drawings.

   g. **Detail drawing**— A drawing containing the necessary information to completely manufacture a single part or one stage of a single part

   h. **Engineering change note (ECN)** — An approved change to a drawing caused by a change in design, tool changes, errors in design or production, or customer changes

   i. **Forging drawing** — A detail drawing of a workpiece to be forged in dies

   j. **Revision** — A change made on a drawing

   k. **Title** — The name of an object or a project

   l. **Title form** — A standardized place to show all information not shown with notes and dimensions on a drawing

   m. **Zoning** — Equal intervals along the margins labeled with numbers along the horizontal margin and with letters along the vertical margin for locating an area on a drawing

Information Sheet

2. Information found on title strips and title blocks

a. Standard information

(1) Name of the object represented

(2) Name and address of the industry

(3) Name and address of the client, if any

(4) Number of drawing which may include sheet letter size

(5) Revision letter

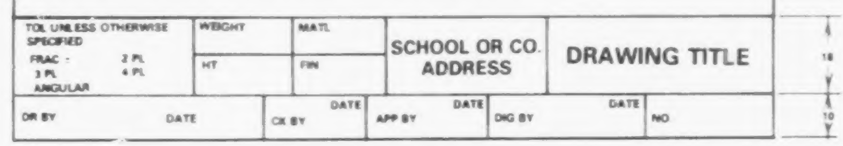
(6) Signature of drafter with date of completion

(7) Signature of checker with date of completion

(8) Signature of designer, engineer, or other official and date approved

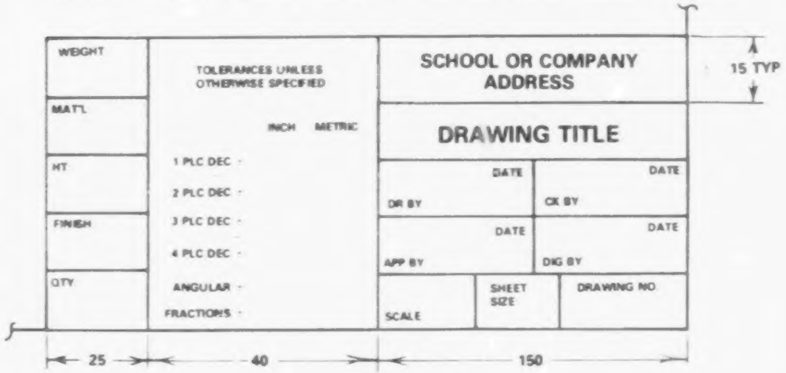
(9) Predominate scale of drawing

(10) Sheet number for multiple sheets


TOL UNLESS OTHERWISE SPECIFIED
FRAC -
2 PL
3 PL
4 PL
ANGULAR
WEIGHT
MAT'L
HT
FIN
SCHOOL OR CO. ADDRESS
DRAWING TITLE
18
DR BY
DATE
DATE
CK BY
DATE
APP BY
DATE
DIG BY
NO
10

Title Strip

(NOTE: All lettering is 3mm high except Title and Drawing numbers which are 6mm high.)


WEIGHT
MAT'L
HT
FINISH
QTY
TOLERANCES UNLESS OTHERWISE SPECIFIED
INCH
METRIC
1 PLC DEC -
2 PLC DEC -
3 PLC DEC -
4 PLC DEC -
ANGULAR -
FRACTIONS -
SCHOOL OR COMPANY ADDRESS
15 TYP
DRAWING TITLE
DATE
DR BY
DATE
CK BY
DATE
APP BY
DATE
DIG BY
SCALE
SHEET SIZE
DRAWING NO
25
40
150

Title Block

Information Sheet

b. Additional information

(1) Tolerances

(2) Material

(3) Heat treatment

(4) Quantity

(5) Finish

(6) Hardness

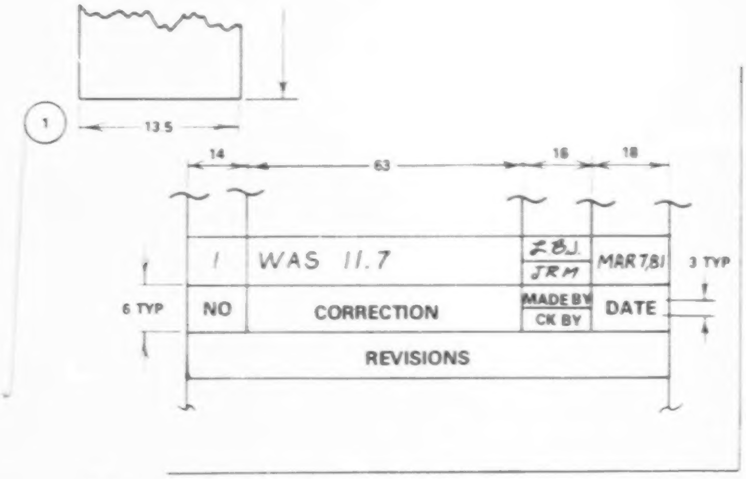
(7) Weight

(8) Superseding note

(9) Company logos

(10) Other peculiarities of the product

3. Information found on a revision block


1
13.5
14
63
16
18
1
WAS 11.7
Z.B.J.
JRM
MAR 7,81
3 TYP
6 TYP
NO
CORRECTION
MADE BY
CK BY
DATE
REVISIONS

Revision Form Without Zones

Information Sheet

a. Letter or number of change(s)

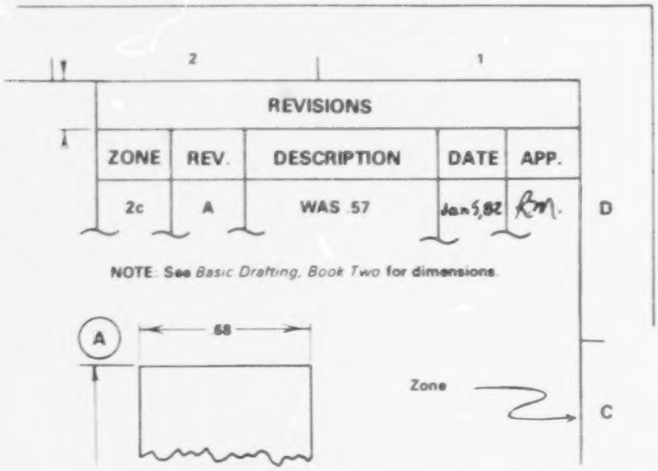
b. Description of correction or change

c. Person making change

d. Person checking change

e. Date of change

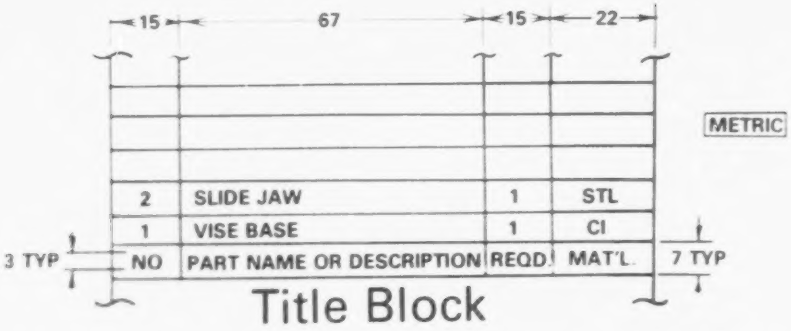
f. Zone for location of change


2
1
REVISIONS
ZONE
REV.
DESCRIPTION
DATE
APP.
2c
A
WAS .57
Jan 5,82
RM.
D
NOTE: See *Basic Drafting, Book Two* for dimensions.
A
.68
Zone
C

Revision Form With Zones

Information Sheet

4. **Information on a bill of materials/parts list**


15
67
15
22
METRIC
2
SLIDE JAW
1
STL
1
VISE BASE
1
CI
3 TYP
NO
PART NAME OR DESCRIPTION
REQD.
MAT'L.
7 TYP
Title Block

Parts List--Short Form Over Title Block

a. Standard information

   (1) Item number referring to assembly drawing

   Note: Item numbers are sometimes referred to as dash numbers.

   (2) Part name

   (3) Number required

   (4) Material from which part is made

b. Additional information

   (1) Stock number

   (2) Description or nomenclature

   (3) Address of vender

   (4) Unit of measure

   Note: These units include grams, pieces, feet, pounds, or gallons.

   (5) Group subassembly where used

   (6) Approval

   (7) Release date

Information Sheet

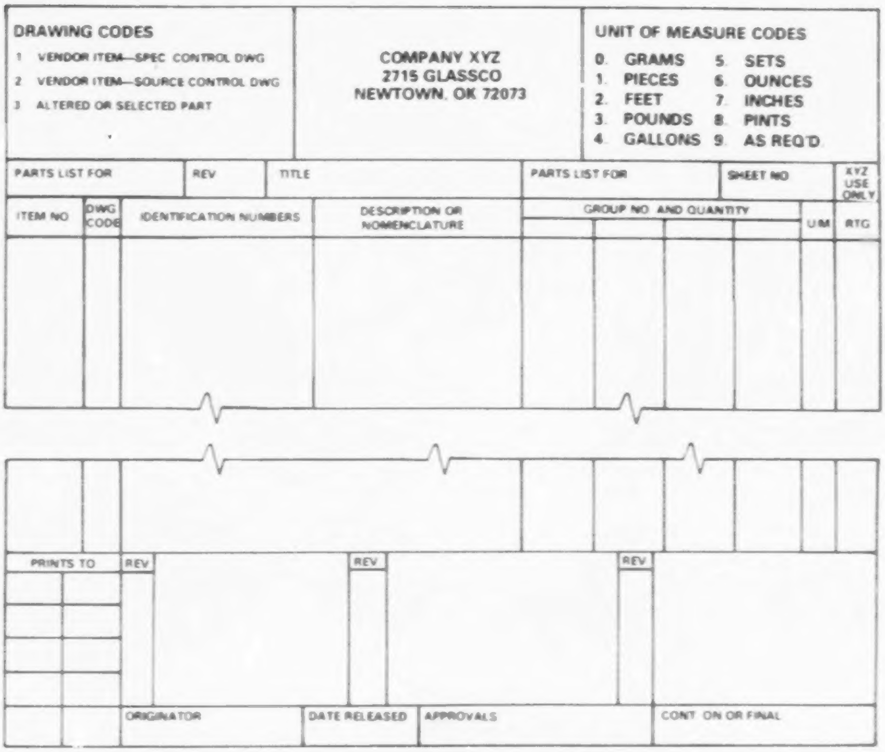
(8) Originator

(9) Revision

(10) Stock size

(11) Pattern number

(12) Weight



DRAWING CODES
1 VENDOR ITEM—SPEC CONTROL DWG
2 VENDOR ITEM—SOURCE CONTROL DWG
3 ALTERED OR SELECTED PART

COMPANY XYZ
2715 GLASSCO
NEWTOWN, OK 72073

UNIT OF MEASURE CODES

0.	GRAMS	5.	SETS
1.	PIECES	6.	OUNCES
2.	FEET	7.	INCHES
3.	POUNDS	8.	PINTS
4.	GALLONS	9.	AS REQ'D

PARTS LIST FOR	REV	TITLE	PARTS LIST FOR	SHEET NO	XYZ USE ONLY

ITEM NO	DWG CODE	IDENTIFICATION NUMBERS	DESCRIPTION OR NOMENCLATURE	GROUP NO AND QUANTITY				U/M	RTG

PRINTS TO

REV

REV

REV

ORIGINATOR

DATE RELEASED

APPROVALS

CONT ON OR FINAL

Bill of Materials/Parts List

Information Sheet

5. **Stages in the design process**

   a. **Problem identification** starts the design process with a plan of action which includes available information, time parameters, costs, defined function, limits, and market potential; if a CAD operator does a good job here, the solution will follow much faster.

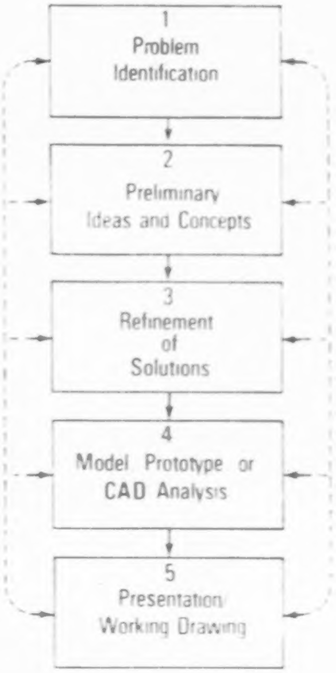
   b. **Preliminary ideas and concepts** are the next stage which includes brainstorming using background information from technical literature, reports, design and trade journals, patents, and existing products; start and update a project notebook to include signatures and dates of inventors and witnesses.

   c. **Refinement of solutions** is the next stage where design layouts, functional features, stress analysis, ease of assembly, serviceability, and manufacturability are refined for the most promising solutions.

   d. **Model, prototype, or CAD analysis** is the stage in which the design is analyzed and refined to prove that the design works; this is an important step that may require going back to previous steps or using CAD construction of prototypes using wireframes and solids to replace preliminary prototypes; here's where shading and light source can give the design a realistic appearance.

   e. **Presentation/working drawings** is the stage for formal documentation for production; this final stage includes detail drawings, assembly drawings, and parts list; rendered 3D presentation drawings produced with CAD; models or prototypes; the primary focus at this point is to sell the idea or product to others.

Design Process


1
Problem Identification
2
Preliminary Ideas and Concepts
3
Refinement of Solutions
4
Model, Prototype or CAD Analysis
5
Presentation/ Working Drawing

Information Sheet

6. Design layouts and their characteristics

a. Design layouts are drawn by a designer as part of the design process.

b. The degree of detail needed on a layout depends on the degree of competency of the drafter.

Example: A skilled drafter will require very little detail, but a drafter not well trained requires a great deal of detail.

c. The layout must be drawn accurately with thin lines on CAD or board.

d. Layouts usually include only critical dimensions.

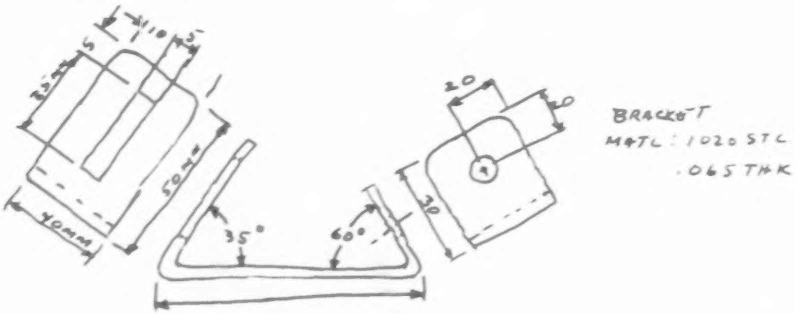
Note: A design layout should include what the project demands, and this might include everything from accurate-to-scale details of each part to special manufacturing problems; many times, calculations for strength, function, cost, and weight are required.

> **CAD Alert:** Using a CAD system is the best way to complete a design layout. The CAD design is easy to transfer to any CAD operator to complete the details.

7. Basic elements of a design layout sketch

a. Design layout sketches do not have to be drawn accurately to prove that something works.

b. A designer or engineer will simply sketch a layout and leave it to a drafter to make the detail drawing.



Information Sheet

c. Otherwise, layout sketches should include all vital information including projection, multiview or isometric, and proper line symbols and darkness.

d. Calculations should be made as needed for strength, function, cost, and weight.

e. Recommend standard parts when possible and include notes for them along with notes for special processes or anticipated manufacturing problems.

f. Include proportion information and shape or form dimensions along with all critical dimensions.

g. Include ease of assembly and ease of serviceability.

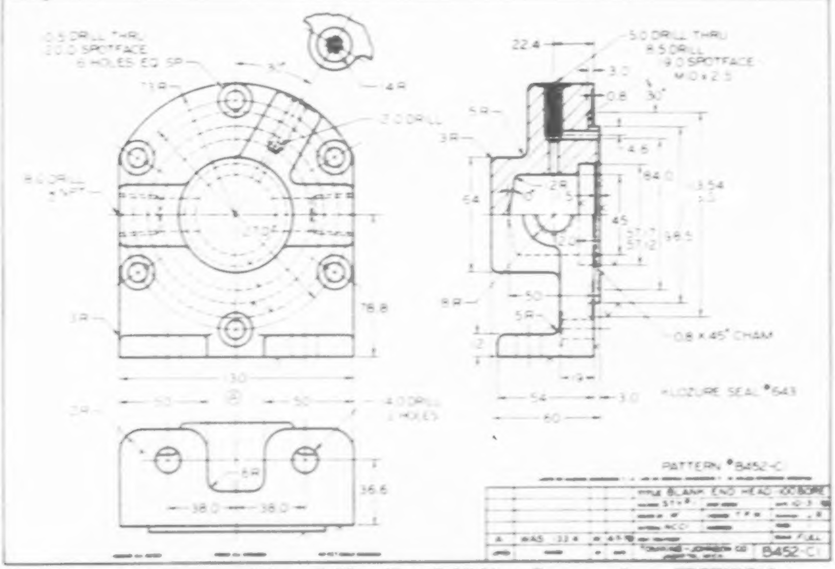
Note: This list is only a partial list of items that could appear on a sketch. Remember to include all information a potential client would need to visualize the product, its function, and its manufacturability.

8. **Standard parts of a detail drawing and their functions**

a. **Shape description** — Includes multiview, auxiliary, sections, and/or pictorials

b. **Dimensions** — Includes size, location, and tolerances

c. **Notes** — May be general or specific to include materials, processes, or other specifications


10.5 DRILL THRU
20.0 SPOTFACE
6 HOLES EQ SP
30°
14R
11R
2.0 DRILL
8.0 DRILL
3R
78.8
130
50
50
4.0 DRILL
2 HOLES
2R
6R
38.0
38.0
36.6
22.4
5.0 DRILL THRU
8.5 DRILL
19.0 SPOTFACE
M10 x 2.5
3.0
0.8
30°
5R
3R
4.6
84.0
64
12R
45
8R
50
5R
0.8 X 45° CHAM
19
54
3.0
60
KLOZURE SEAL #643
PATTERN #B452-C
BLANK, END HEAD
B452-C1

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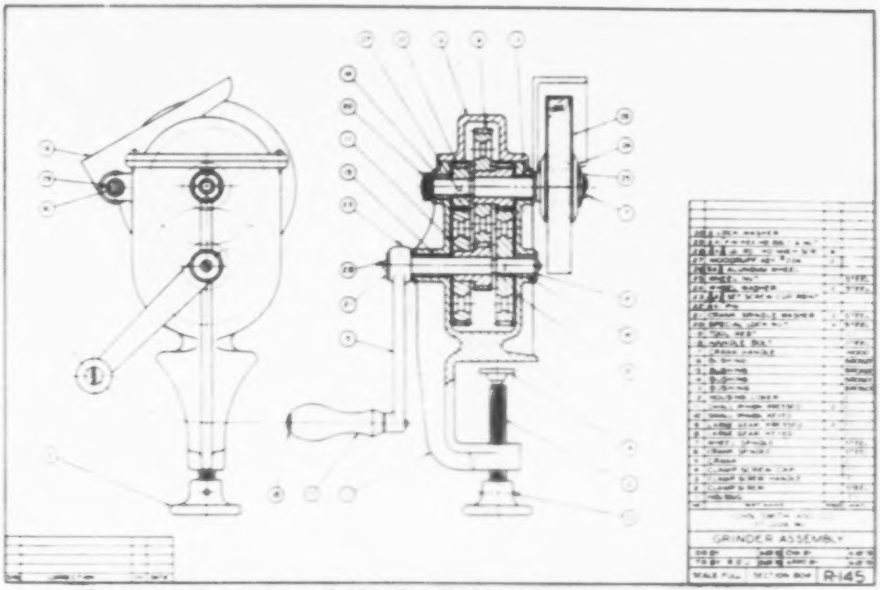
Information Sheet

9. Parts of an assembly drawing and their functions



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a. **Views** — Shows the relationship of parts, not the shapes of individual parts

b. **Sections** — Show the inside function or construction of parts

c. **Hidden lines** — Used only to promote clarity, but unnecessary when several sections are used; might actually confuse the reading of the drawing

d. **Dimensions** — Show maximum or minimum sizes or locations of machine parts after assembly and overall size; only certain dimensions and notes are given

e. **Parts identification numbers** — Allow for quick identification of physical shape, and guide reader to the parts list

Note: An identification number should be 5mm high in a 12mm circle, and the circle should be connected to the part with an arrowhead, dot, or S; avoid vertical and horizontal leaders.

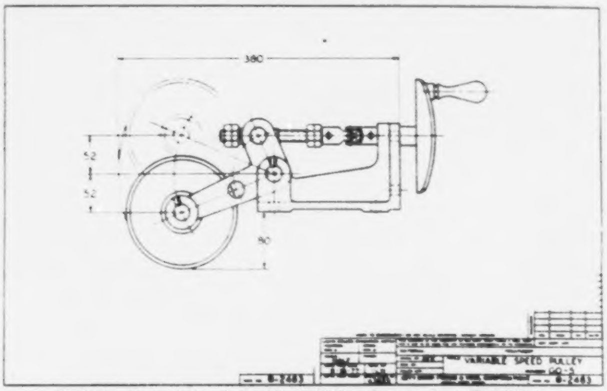
Information Sheet

10. Information on outline or installation assembly drawings

a. Assemblies present the method for installing or erecting a machine or structure.

b. Assemblies outline and show relationships of external surfaces.

c. Assemblies show relationship of final positioning for subassemblies.


380
52
52
90
VARIABLE SPEED PULLEY
B-2443
B-2443

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11. Information on weldment assembly drawings

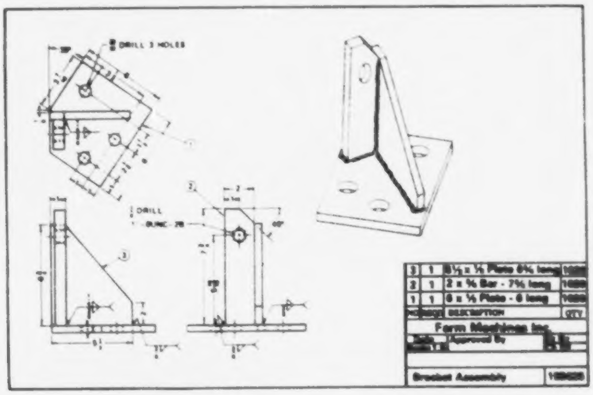
a. Parts identification

b. Dimensioning, including the detailed or after-welding final dimensions; proper jigs must be used to prevent distortion and maintain final dimensions

c. Standard welding symbols from ANSI Standard Y32.3-1969

d. Parts list; parts may be from stock

e. Multiviews and auxiliary views, if used, but sections are normally not used


DRILL 3 HOLES
DRILL
UNC-2B
60°
3 1 3½ x ½ Plate 6¾ long
2 1 2 x ⅝ Bar - 7⅝ long
1 1 6 x ½ Plate - 6 long
DESCRIPTION
QTY
Farm Machines Inc.
Approved by
Bracket Assembly

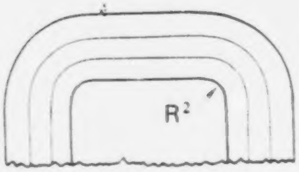
Information Sheet

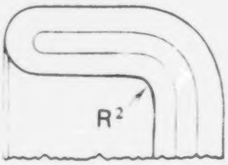
12. **Parts of forging drawings and their characteristics (ANSI Y14.9-1958)**

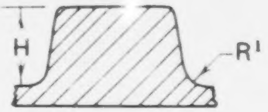
    a. **Fillets and rounds** — Minimum sizes

    b. **Parting line** — Separation of upper and lower dies

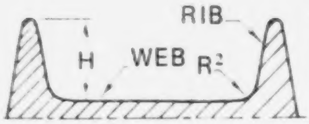
    c. **Draft** — Ease in removal from dies



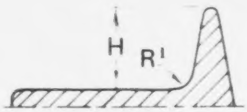




Boss



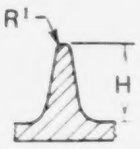
Opposing Ribs--
Confined Metal in Web



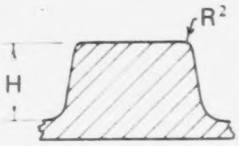
Single Rib

H	R^1	R^2
1/4	1/8	1/8
1/2	1/8	1/8
1	1/4	3/8
2	1/2	5/8
3	3/4	1
4	1	1 3/8
5	1 1/4	1 3/4
6	1 1/2	2

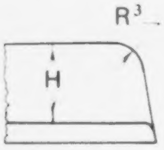
FILLET RADII



Rib



Boss



End of Rib

H	R^1	R^2	R^3
1/4	1/16	1/16	3/16
1/2	1/16	1/16	3/16
1	1/8	1/8	3/8
2	3/16	1/4	1/2
3	1/4	5/16	3/4
4	5/16	7/16	1
5	3/8	1/2	1 1/8
6	7/16	5/8	1 1/4
7	1/2	11/16	1 1/2

CORNER RADII

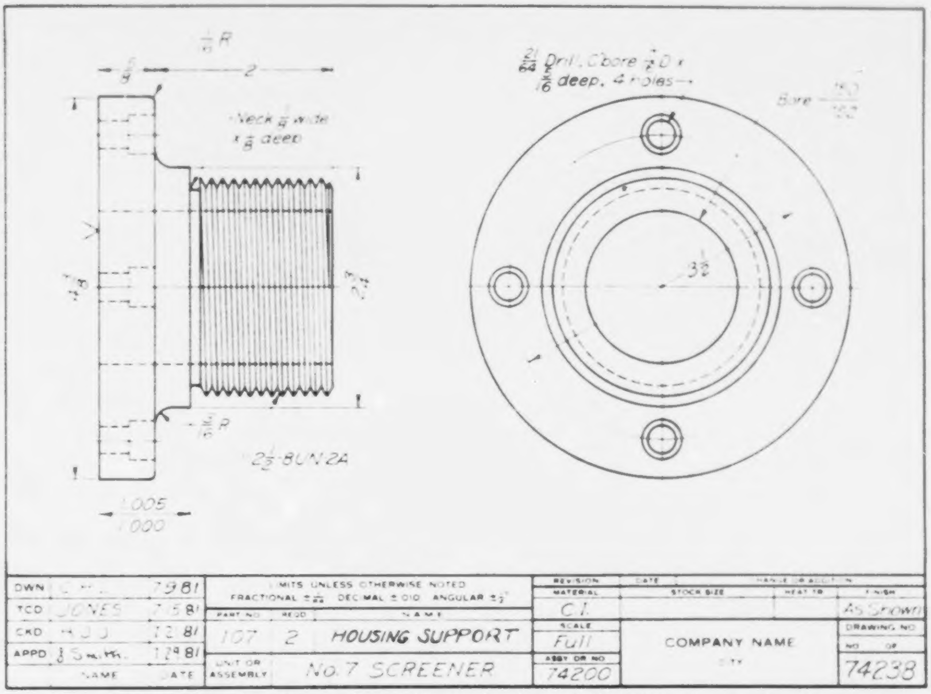
Information Sheet

13. **Parts of a pattern or casting drawing and their characteristics**

    a. **Fillets and rounds** — Minimum sizes

    b. **Parting line** — Separation of one mold from the other

    Note: A draft is sometimes included by the pattern maker, but it is not shown on the casting drawing.


1/16 R
5/8
2
Neck 1/8 wide
× 1/8 deep
4 7/8
2 3/4
3/16 R
2 1/2-8UN-2A
1.005
1.000
21/64 Drill, C'bore 1/2 D ×
5/16 deep, 4 holes
Bore
3 1/2
DWN
7 9 81
TCD
JONES
7 15 81
CKD
7 21 81
APPD
J. Smith
7 29 81
NAME
DATE
LIMITS UNLESS OTHERWISE NOTED
FRACTIONAL ± 1/64 DECIMAL ±.010 ANGULAR ± 1/2°
PART NO.
REQD
NAME
107
2
HOUSING SUPPORT
UNIT OR ASSEMBLY
No. 7 SCREENER
REVISION
DATE
MATERIAL
STOCK SIZE
HEAT TR
FINISH
C.I.
As Shown
SCALE
Full
ASSY OR NO
74200
COMPANY NAME
CITY
DRAWING NO
NO
OF
74238

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Layouts and Working Drawings
Unit 12

Assignment Sheet 1—Draw a Design Layout

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Degree of difficulty of selected design layout	______
Drawing and lettering techniques	______
CAD application (if applicable)	______

Directions: Select a project from the following list or a project assigned by your instructor. First, sketch the desired layout to include standard parts and fixed dimensions. Draw your design layout on appropriate media. Letter information in its proper place with correct lettering techniques, and remember: you are not making a detail drawing, but only a drawing to show the information necessary for a drafter.

CAD Alert: Use a CAD system to create your design layout.

1. Design a sports car exterior.
2. Design a speed boat exterior.
3. Design a toaster exterior.
4. Design a stereo system exterior.
5. Design a go-cart exterior.
6. Design a fast wheel chair.
7. Design a toy.
8. Design a kitchen tool.
9. Design a tool or wrench to work on a car.
10. Design a teaching aid.

Layouts and Working Drawings
Unit 12

Assignment Sheet 2—Draw a Set of Detail Drawings

Name ______________________ Overall Rating __________

Evaluation criteria	Rating
Placement of dimensions, tolerances, and notes	______
Drawing and lettering techniques	______
General functional quality of project	______
CAD application (if applicable)	______

Directions: Use the design layout you created in Assignment Sheet 1. Sketch each detail to include proper placement of dimensions, tolerances, and notes. Tape drawing media to drawing surface, and draw each detail on a *separate* sheet of paper of appropriate size. Letter information in its proper place using correct lettering techniques.

CAD Alert: Use a CAD system to create your detail drawings.

Layouts and Working
Drawings
Unit 12

Assignment Sheet 3—Draw an Assembly Drawing

Name ______________________________ Overall Rating __________

Evaluation criteria	Rating
Use of sections, views, and dimensions	_____
Drawing and lettering techniques	_____
General functional quality of project	_____
CAD application (if applicable)	_____

Directions: Use a layout from Assignment Sheet 1 or details from Assignment Sheet 2, or a project selected by your instructor. Sketch an assembly drawing to include appropriate sections, views, and dimensions. Tape drawing media to drawing surface, and draw the assembly drawing. Letter information in its proper place using correct lettering techniques.

CAD Alert: Use a CAD system to create your assembly drawing.

Layouts and Working
Drawings
Unit 12

Assignment Sheet 4—Complete a Detailed Title Block and Revision Block

Name ______________________________ Overall Rating __________

Evaluation criteria	Rating
Correct pencil selection	______
Correct title block for detail presentation	______
General functional quality of project	______

Directions: With a lettering guide and the drawing media from Assignment Sheet 2 and 3, use the procedure in the following example to complete a detailed title block and revision block.

CAD Alert: Use a CAD system to construct a border and title block, and add appropriate information. Create data for each size drawing: A, B, C, D, and E. Save as a pattern or block to be used with future drawings.

Example:

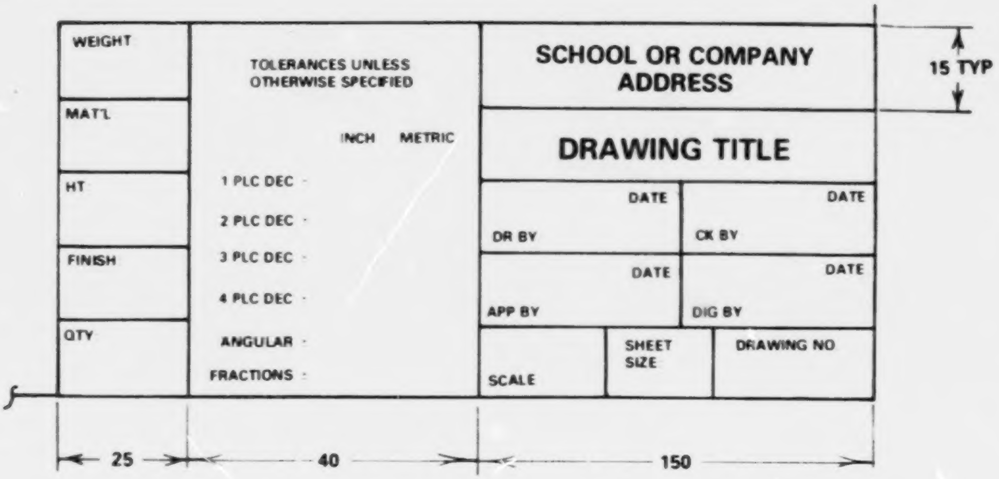
1. Tape drawing media to drawing surface.
2. Select correct pencils.

Assignment Sheet 4

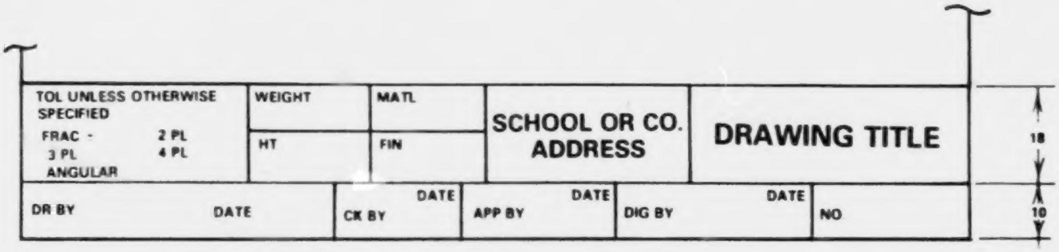
3. Select appropriate title block for detail information.

   Note: Refer to the following examples of title strips and title blocks. Select one shown or devise one of your own which has been approved by the instructor.

Example:


WEIGHT
MAT'L
HT
FINISH
QTY
TOLERANCES UNLESS OTHERWISE SPECIFIED
INCH
METRIC
1 PLC DEC -
2 PLC DEC -
3 PLC DEC -
4 PLC DEC -
ANGULAR -
FRACTIONS -
SCHOOL OR COMPANY ADDRESS
DRAWING TITLE
DR BY
DATE
CK BY
DATE
APP BY
DATE
DIG BY
DATE
SCALE
SHEET SIZE
DRAWING NO
15 TYP
25
40
150

Note: This title block can be used with "C," "D," and "E" size sheets.


TOL UNLESS OTHERWISE SPECIFIED
FRAC -
2 PL
3 PL
4 PL
ANGULAR
WEIGHT
MAT'L
HT
FIN
SCHOOL OR CO. ADDRESS
DRAWING TITLE
DR BY
DATE
CK BY
DATE
APP BY
DATE
DIG BY
DATE
NO
18
10

Note: This title block can be used with "A" and "B" size sheets.

4. Draw title block in lower right hand corner.
5. Draw guidelines for lettering.
6. Letter in information in its proper place using correct lettering techniques.

Assignment Sheet 4

7. Select revision block containing zone reference.
8. Draw revision block in upper right hand corner.
9. Letter in information in its proper place using correct lettering techniques.

Layouts and Working Drawings
Unit 12

Assignment Sheet 5—Complete a Parts List

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Creation of parts list form	______
Lettering selection and technique	______
General functional qulaity of project	______
CAD application (if applicable)	______

Directions: On a drawing surface, tape down either the drawing from Assignment Sheet 3 or a separate parts list. Letter in the parts using correct lettering technique.

CAD Alert: Use a CAD system to produce the text for your parts list, or use a word processor to produce the parts list text, then check text with a spell checker, save as an ASCII file, and then insert the text into the drawing.

Layouts and Working Drawings
Unit 12

Assignment Sheet 6—Make a Drawing Revision

Name ______________________________ Overall Rating __________

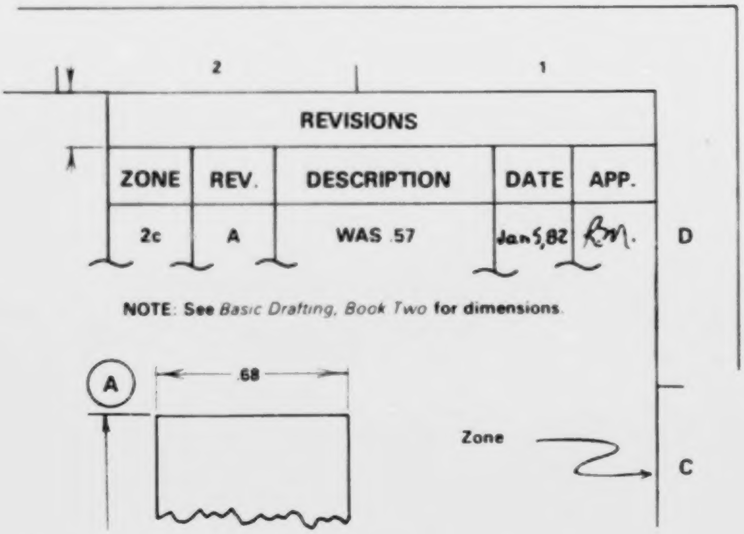
Evaluation criteria	Rating
Revision lettered on drawing and in revision block	______
Revision block signed and dated	______
Blueline print of revision	______

Directions: To make your drawing revision, use drawings from Assignment Sheets 2, 3, or 4, or your instructor may choose to give you an Engineering Change Notice (ECN). Follow the procedure in the example to complete your drawing revision.

> **CAD Alert:** Use a CAD system to create a revision block as a pattern or block. Insert the pattern or block into assignment sheet in the upper right hand corner.

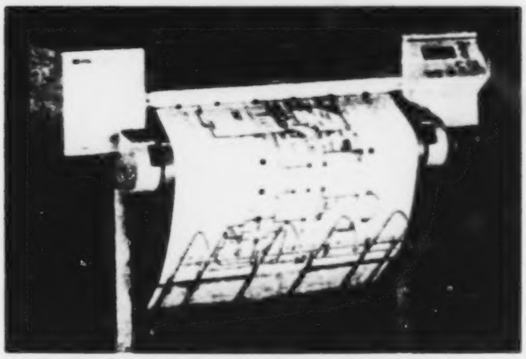
Example:

1. Letter revision on drawing and in revision block.
2. Sign and date revision block.
3. Make a blueline print of the revision and give it to your instructor.



REVISIONS				
ZONE	REV.	DESCRIPTION	DATE	APP.
2c	A	WAS .57	Jan 5,82	R.M.

NOTE: See *Basic Drafting, Book Two* for dimensions.



Courtesy Hewlett-Packard Company

Facility Layout
Unit 13

Objective Sheet

Unit Objective

After completing this unit, the student should be able to develop a flow process chart, a relationship matrix, and create a bubble diagram, a block diagram, and a facility layout. The student should demonstrate these competencies by completing the assignment sheets and by scoring a minimum of 85 percent on the written test.

Specific Objectives

After completing this unit, the student should be able to:

1. Match terms related to facility layout with their correct definitions.
2. Complete statements about situations where facility layouts are needed.
3. Select true statements about advantages of reorganizing a facility layout.
4. Match contents of a flow process chart with their symbols.
5. List types of facilities layouts used in production processes.
6. Complete statements about characteristics of a process layout.
7. Complete statements about characteristics of a product layout.
8. Complete statements about characteristics of a fixed-position layout.
9. Complete statements about characteristics of a group layout.
10. Match stages in building a facility layout with their characteristics.
11. Develop a flow process chart. (Assignment Sheet 1)
12. Develop a relationship matrix. (Assignment Sheet 2)

Objective Sheet

13. Create a bubble diagram. (Assignment Sheet 3)

14. Create a block diagram. (Assignment Sheet 4)

15. Create a facility layout. (Assignment Sheet 5)

Facility Layout
Unit 13

Suggested Activities

Instructional Plan

Preparation

1. Read the unit carefully and plan for instruction.
2. Review Teaching Suggestions section that follows. Plan for classroom activities.
3. Plan for enrichment of exceptional students as well as accommodation of special needs students.
4. Make transparency from the transparency master included with this unit. The transparency "Facility Layout" should be used as students discuss Objective 10 and Assignment Sheet 5.
5. Obtain films, videotapes, and other resources to supplement instruction of this unit. See ordering information in the Suggested Supplemental Resources section that follows.
6. Develop teaching plan. Adjust for different learning styles.

Delivery and Application

7. Make copies of Unit Evaluation Form.
8. Provide students with unit of instruction.
9. Discuss unit and specific objectives.
10. Discuss information sheet. Implement teaching plan to localize, supplement, and personalize the unit. Reinforce basic skills when applicable.
11. Discuss the assignment sheets. Review criteria for evaluation of these activities.

Evaluation

12. Discuss the use of the Unit Evaluation Form with students. Discuss the rating scale that will be used for student evaluation.
13. Make copies of the written test. Add or modify test questions as needed.
14. Give written test.
15. Compile assignment sheet ratings and written test scores on the Unit Evaluation Form. Include any additional assignments.
16. Reteach and retest as required.

Suggested Activities

Teaching Suggestions

Note: Skill areas appearing in boldface type in the Teaching Suggestions refer to the academic and workplace skills identified by the American Society for Training and Development (ASTD) and the U.S. Department of Labor. These have been adapted by MAVCC.

1. Check industries in your area for firms that have reorganized or have changed part or all of their operation for a new process or product. Have an engineer from the firm talk to the class about the planning that went into the change, and how the drafting or CAD work played a significant part in the process. Skill areas: **Foundation skills, listening**.
2. Find other types of flow charts to show to the class as you discuss and study Objective 6. Pass the charts around so students can examine them and get a better idea of what a flow chart really accomplishes. Skill areas: **Learning skills, learning to learn**.
3. Check your area for types of industries that have process layouts, product layouts, fixed-position layouts, or group layouts. Talk about the type or types of products these industries produce, and attempt to show students how the type of layout is important to the type of process and product. Skill areas: **Learning skills, learning to learn**.
4. Arrange for students to visit a production layout facility so they can properly prepare for objectives in Assignment Sheets 3, 4, and 5. Assign teams to work together on these final three assignment sheets, and especially Assignment Sheet 5. These are difficult assignments, and an excellent place to point out to students the advantages of using CAD to permit the exploration of several possible results in a short period of time. Skill areas: **Group effectiveness skills, teamwork**.

Resources Used in Developing This Unit

1. Braver, Roger L. *Production Handbook*, 2nd ed. New York: AMACO, American Management Association, 1992.
2. Carson, Gordon, B. *Production Handbook*, 2nd ed. New York: Ronald Press Co., 1958.
3. Evans, James R., et. al. *Applied Production and Operations Management*, 3rd ed. St. Paul, MN: West Publishing, 1990.
4. Moore, James. *Plant Layout and Design*. New York: Macmillan Publishing Company, 1962.
5. Mother, Richard. *Systematic Layout Planning*. New York: Industrial Education Institute, 1961.

Facility Layout
Unit 13

Answers to Assignment Sheets

Assignment Sheet 1, 2, 3, 4, and 5

Evaluated according to criteria written in the respective assignment sheets.

Facility Layout
Unit 13

Answers to Written Test

1. a. 4 d. 5 g. 9
   b. 6 e. 2 h. 1
   c. 8 f. 7 i. 3

2. a. Articulate drawings
   b. Rate
   c. Products
   d. Processes
   e. Product
   f. Obsolete

3. a, b, e, f, g

4. a. 4 d. 2
   b. 5 e. 3
   c. 1

5. In any order:

   a. Process layout
   b. Product layout
   c. Fixed-position layout
   d. Group layout

6. a. Similar
   b. Investment in equipment
   c. Job

7. a. A continuous
   b. Similar
   c. The same
   d. Permits a small
   e. Less

8. a. The same
   b. Heavy machine tools
   c. Greater

9. a. Similar operations
   b. Cell
   c. Similar
   d. Waiting
   e. Personal

10. a. 3 c. 1
    b. 4 d. 2

Facility Layout
Unit 13

Written Test

Name ______________________________ Date __________________ Score ____________

1. Match the terms on the right with their correct definitions.

   ______a. A pause in the process of work

   ______b. The arrangements of physical facilities for production

   ______c. The analysis of the step by step sequence of operations, storage, transportation, inspections, and delays in a production process

   ______d. Items of production not finished or complete as a final product

   ______e. Checking to make sure an item meets specifications

   ______f. A task performed at one location

   ______g. A fixed sequence of production operations

   ______h. The holding of an item before, during, or after a process

   ______i. The movement of an item from one place to another

   1. Storage
   2. Inspection
   3. Transportation
   4. Delay
   5. In-process inventory
   6. Facility layout
   7. Operation
   8. Flow process chart
   9. Production line

2. Complete statements about situations where facility layouts are needed. Circle the material that best completes each of the following statements.

   a. Construction of a new facility demands (**rough sketches only**) (**articulate drawings**).

   b. Change in production (**workers**) (**rate**) or volume demands physical changes.

   c. The introduction of new (**skilled workers**) (**products**) demands retooling.

Written Test

d. The installation of new equipment or (**storage**) (**processes**) requires design expertise.

e. Changes in an existing (**material**) (**product**) require design changes.

f. When a facility becomes (**old**) (**obsolete**), it should be redesigned.

3. Select true statements about reorganizing a facility layout. Place an "X" beside each true statement.

_______a. Reorganizing improves product quality.

_______b. Reorganizing improves manufacturing flexibility.

_______c. Reorganizing seldom reduces floor space requirements.

_______d. Reorganizing produces a longer cycle time.

_______e. Reorganization lowers the in-process inventory.

_______f. Reorganization reduces the costs of handling inventory.

_______g. Reorganization makes scheduling and control easier.

4. Match contents of a flow process chart with their symbols. Place the number beside the symbol in the blank beside the definition of its contents.

_______a. Operation 1. □

_______b. Transportation 2. D

_______c. Inspection 3. ▽

_______d. Delay 4. ○

_______e. Storage 5. ⇨

Written Test

5. List four types facilities layouts used in production processes. Items may be arranged in any order.

   a. ______________________________

   b. ______________________________

   c. ______________________________

   d. ______________________________

6. Complete statements about characteristics of a process layout. Circle the material that best completes each of the following statements.

   a. All (**small**) (**similar**) machines are grouped together.

   b. Job shops usually have a process layout because it lowers (**investment in equipment**) (**personnel skills**).

   c. The diversity of a process layout gives workers higher (**product**) (**job**) satisfaction.

7. Complete statements about characteristics of a product layout. Circle the material that best completes each of the following statements.

   a. Product layout provides (**a continuous**) (**an alternating**) flow or path for raw material to finished product.

   b. Product layout is used for mass production of (**similar**) (**the same**) product.

   c. Product layout performs (**an alternating**) (**the same**) sequence of operations in a logical flow of production.

   d. Product layout (**demands a large**) (**permits a small**) in-process inventory and since there is less material handling, production time is short.

   e. With product layout, there is (**more**) (**less**) flexibility in major product changes, and some production operations are monotonous for operators.

Written Test

8. Complete statements about the characteristics of a fixed-position layout. Circle the material that best completes each of the following statements.

   a. With fixed-position, a product stays in (**the same**) (**a flexible**) position, and tools and equipment for assembly are brought to the same position.

   b. Fixed-position layout is used on large products such as airplanes, locomotives, or (**heavy machine tools**) (**automobiles**).

   c. Fixed-position layout permits (**fewer**) (**greater**) changes in design and product mix, and capital investment is held to a minimum.

9. Complete statements about the characteristics of a group layout. Circle the information that best completes each of the following statements.

   a. In group layout, parts are classified into families with (**similar operations**) (**exact characteristics**).

   b. Group layout is organized in a (**loose block**) (**cell**) with machines to produce a family of parts.

   c. When parts have (**basic**) (**similar**) features, retooling is easier.

   d. Since material handling is reduced, (**retooling**) (**waiting**) and throughput time are reduced.

   e. Each worker in a group layout cell inspects a part before passing it on to the next operator, and (**inspection**) (**personal**) involvement adds to higher job satisfaction.

Written Test

10. Match stages in building a facility layout with their characteristics. Place the number beside the stage in the blank beside the definition of its characteristic.

_______a. Used to establish how spaces should be physically positioned relative to each other

_______b. Used to establish relationships among spaces to designers

_______c. A rough approximation of the physical size of each space with the correct relationship of spaces relative to each other

_______d. An accurate scale drawing showing the physical location of each piece of equipment

1. Block diagram
2. Detailed floor plan
3. Relationship matrix
4. Bubble diagram

***Permission to duplicate this test is granted.**

Facility Layout
Unit 13

Unit Evaluation Form

Student Name ______________________________ Unit Rating __________

Assignment Sheet 1—Develop a Flow Process Chart Rating ______

Comments: ______________________________

____

Assignment Sheet 2—Develop a Relationship Matrix Rating ______

Comments: ______________________________

____

Assignment Sheet 3—Create a Bubble Diagram Rating ______

Comments: ______________________________

____

Assignment Sheet 4—Create a Block Diagram and Revision Block Rating ______

Comments: ______________________________

____

Assignment Sheet 5—Create a Facility Layout Rating ______

Comments: ______________________________

____

Written Test Scores

Pretest ______ Posttest ______ Other ______

Other ______________________________

____

Teacher Signature ______________________________ Date __________

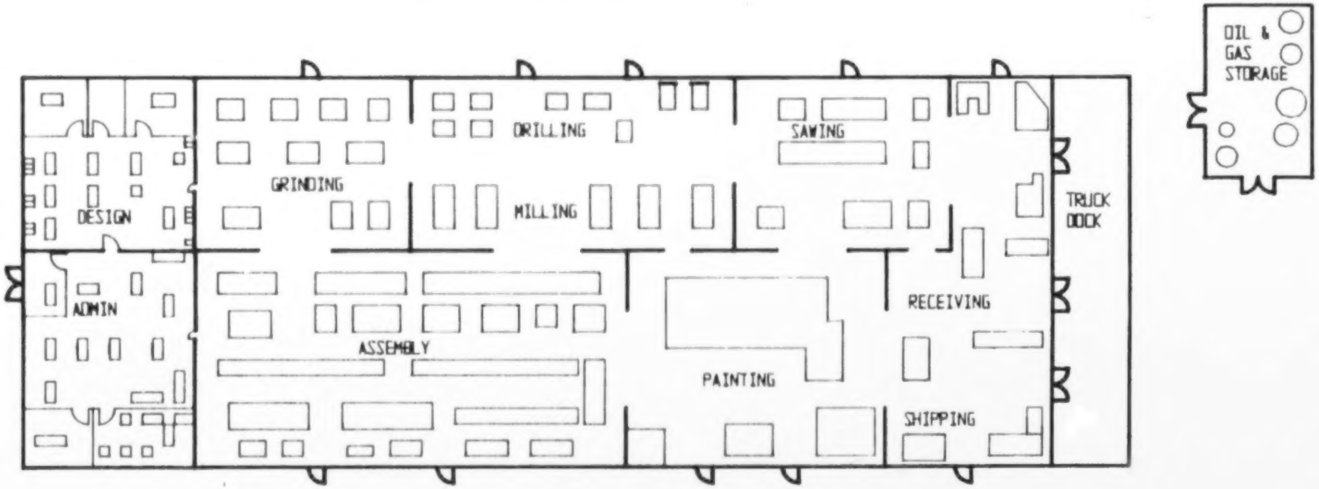
Student Signature ______________________________ Date __________

***Permission to duplicate this form is granted.**

Facility Layout

EXAMPLE FACILITY LAYOUT

USING THE BLOCK LAYOUT AND DETAILS
OF EQUIPMENT AND FURNITURE THE FACILITIES
DESIGNER CREATES A FACILITY LAYOUT.


OIL & GAS STORAGE
DESIGN
GRINDING
DRILLING
MILLING
SAWING
TRUCK DOCK
ADMIN
ASSEMBLY
PAINTING
RECEIVING
SHIPPING

Facility Layout
Unit 13

Information Sheet

1. **Terms and definitions**

    a. **Delay** — A pause in the process of work

    b. **Facility layout** — The arrangements of physical facilities for production

    c. **Flow process chart** — The analysis of the step by step sequence of operations, storage, transportation, inspections, and delays in a production process

    d. **In-process inventory** — Items of production not finished or complete as a final product

    e. **Inspection** — Checking to make sure an item meets specifications

    f. **Operation** — A task performed at one location

    g. **Production line** — A fixed sequence of production operations

    h. **Storage** — The holding of an item before, during, or after a process

    i. **Transportation** — The movement of an item from one place to another

2. **Situations where facility layouts are needed**

    a. Construction of a new facility demands articulate drawings.

    b. Change in production rate or volume demands physical changes.

    c. The introduction of new products demands retooling.

    d. The installation of new equipment or processes requires design expertise.

    e. Changes in an existing product require design changes.

    f. When a facility becomes obsolete, it should be redesigned.

3. **Advantages of reorganizing a facility layout**

    a. Reorganizing improves product quality.

    b. Reorganizing improves manufacturing flexibility.

    c. Reorganizing reduces floor space requirements.

Information Sheet

d. Reorganizing produces a shorter cycle time.

e. Reorganization lowers the in-process inventory

f. Reorganization reduces the costs of handling inventory.

g. Reorganization makes scheduling and control easier.

4. Contents of a flow process chart and their symbols

a. ○ = Operations

b. ⇨ = Transportation

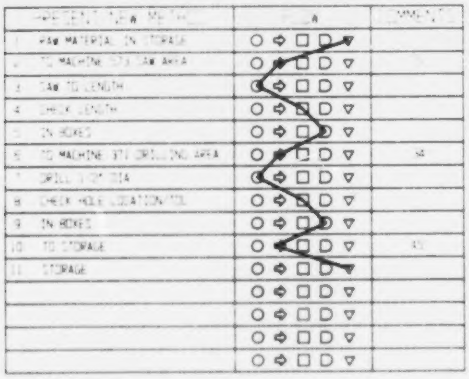
c. □ = Inspection

d. D = Delay

e. ▽ = Storage

FLOW PROCESS CHART EXAMPLE

PART NAME: ANGLE PLATE
PART NUMBER: 375962
PROCESS DESCRIPTION: CUT ANGLE PLATE AND DRILL HOLES
CHARTED BY: TOM SMITH
DATE: 2/17



PRESENT/NEW METHOD	FLOW	COMMENTS
1 RAW MATERIAL IN STORAGE	○ ⇨ □ D ▼	
2 TO MACHINE 573 SAW AREA	○ ➡ □ D ▽	[illegible]
3 SAW TO LENGTH	● ⇨ □ D ▽	
4 CHECK LENGTH	○ ⇨ ■ D ▽	
5 IN BOXES	○ ⇨ □ ◗ ▽	
6 TO MACHINE 371 DRILLING AREA	○ ➡ □ D ▽	54
7 DRILL 1/2" DIA	● ⇨ □ D ▽	
8 CHECK HOLE LOCATION/TOL	○ ⇨ ■ D ▽	
9 IN BOXES	○ ⇨ □ ◗ ▽	
10 TO STORAGE	○ ➡ □ D ▽	45
11 STORAGE	○ ⇨ □ D ▼	
	○ ⇨ □ D ▽	
	○ ⇨ □ D ▽	
	○ ⇨ □ D ▽	
	○ ⇨ □ D ▽	

SUMMARY	NUMBER
OPERATIONS	2
TRANSPORTATION	3
INSPECTIONS	2
DELAYS	2
STORAGES	2
DISTANCE TRAVELED	154'

Information Sheet

5. **Types of facilities layouts used in production processes**

   a. Process layout

   b. Product layout

   c. Fixed-position layout

   d. Group layout

6. **Characteristics of a process layout**

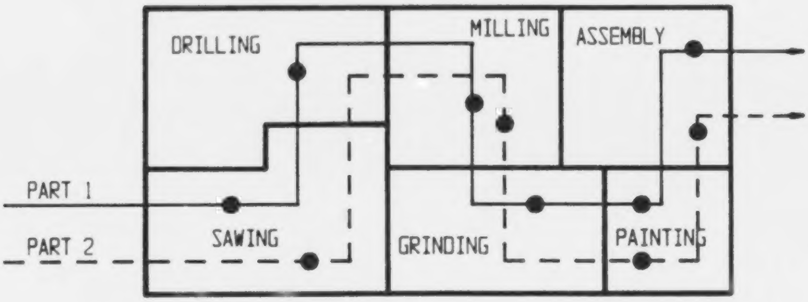
   a. All similar machines are grouped together.

   Example: All drilling processes are grouped together, and all milling machines are grouped together.

   b. Job shops usually have a process layout because it lowers investment in equipment.

   c. The diversity of a process layout gives workers higher job satisfaction.

EXAMPLE OF A PROCESS LAYOUT



7. **Characteristics of a product layout**

   a. Product layout provides a continuous flow or path for a product from raw material to finished product.

   b. Product layout is used for mass production of the same product.

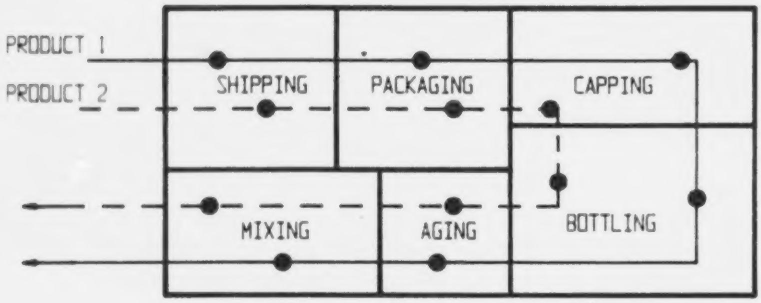
   c. Product layout performs the same sequence of operations in a logical flow of production.

Information Sheet

d. Product layout permits a small in-process inventory and since there is less material handling, production time is short.

e. With product layout, there is less flexibility in major product changes,and some production operations are monotonous for operators.

EXAMPLE OF A PRODUCT LAYOUT


PRODUCT 1
PRODUCT 2
SHIPPING
PACKAGING
CAPPING
MIXING
AGING
BOTTLING

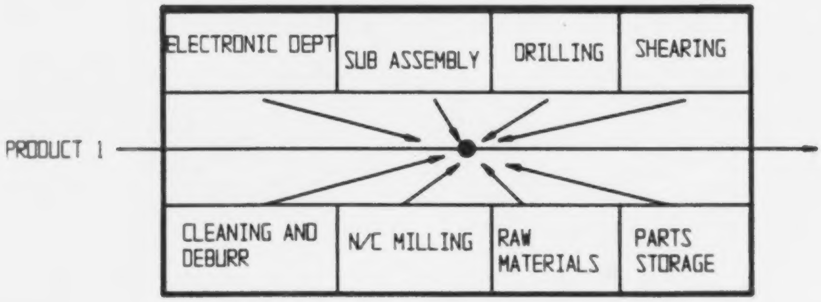
8. Characteristics of a fixed-position layout

a. With fixed-position, a product stays in the same position, and tools and equipment for assembly are brought to the same position.

b. Fixed-position layout is used on large products such as airplanes, locomotives, or heavy machine tools.

c. Fix-position layout permits greater changes in design and product mix, and capital investment is held to a minimum.

EXAMPLE OF A FIXED POSITION LAYOUT


ELECTRONIC DEPT
SUB ASSEMBLY
DRILLING
SHEARING
PRODUCT 1
CLEANING AND DEBURR
N/C MILLING
RAW MATERIALS
PARTS STORAGE

Information Sheet

9. **Characteristics of a group layout**

   a. In group layout, parts are classified into families with similar operations.

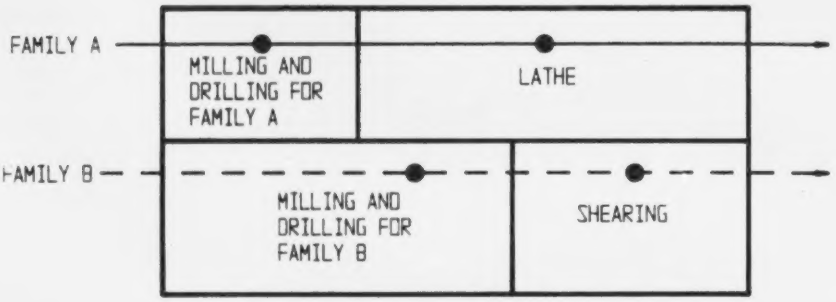
   b. Group layout is organized in a cell with machines to produce a family of parts.

   c. When parts have similar features, retooling is easier.

   d. Since material handling is reduced, waiting and throughput time are reduced.

   e. Each worker in a group layout cell inspects a part before passing it on to the next operator, and personal involvement adds to higher job satisfaction.

EXAMPLE OF A GROUP LAYOUT


FAMILY A
MILLING AND DRILLING FOR FAMILY A
LATHE
FAMILY B
MILLING AND DRILLING FOR FAMILY B
SHEARING

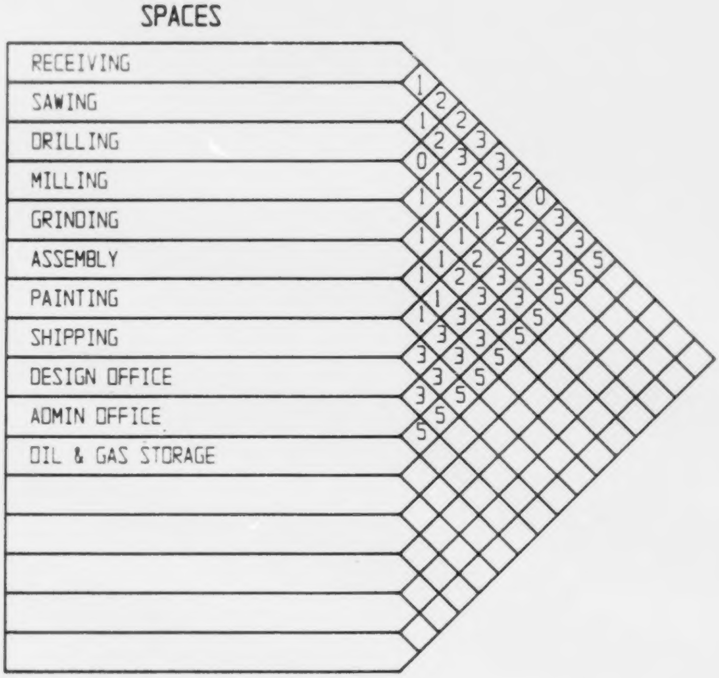
Information Sheet

10. Stages and their characteristics in building a facility layout

a. **Relationship matrix** — Used to establish how spaces should be physically positioned relative to each other

Example: Should spaces be adjacent? Is adjacency preferred, but not absolutely necessary? Is it okay to place the space anywhere? Is distance important? Should spaces be simply apart or in separate buildings?

RELATIONSHIP MATRIX EXAMPLE



SPACES	SAWING	DRILLING	MILLING	GRINDING	ASSEMBLY	PAINTING	SHIPPING	DESIGN OFFICE	ADMIN OFFICE	OIL & GAS STORAGE
RECEIVING	1	2	2	3	3	2	0	3	3	5
SAWING		1	2	3	2	3	2	3	3	5
DRILLING			0	1	1	1	2	3	3	5
MILLING				1	1	1	2	3	3	5
GRINDING					1	1	2	3	3	5
ASSEMBLY						1	1	3	3	5
PAINTING							1	3	3	5
SHIPPING								3	3	5
DESIGN OFFICE									3	5
ADMIN OFFICE										5

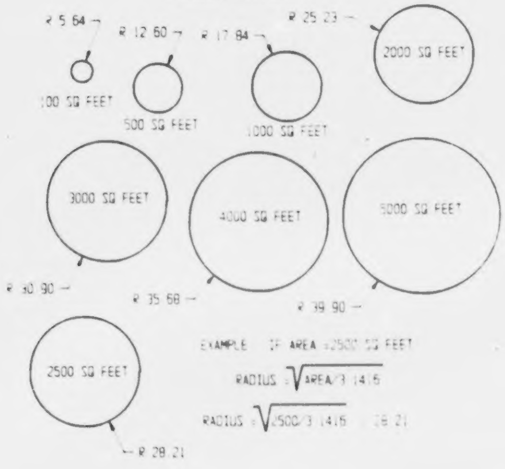
0--SAME SPACE
1--SPACES MUST BE ADJACENT.
2--ADJACENCY PERFERED, BUT NOT ABSOLUTELY NECESSARY.
3--PLACE THE SPACE ANYWHERE.
4--DISTANCE IS NOT IMPORTANT.
5--SPACES SHOULD BE APART OR IN DIFFERENT BUILDINGS.

Information Sheet

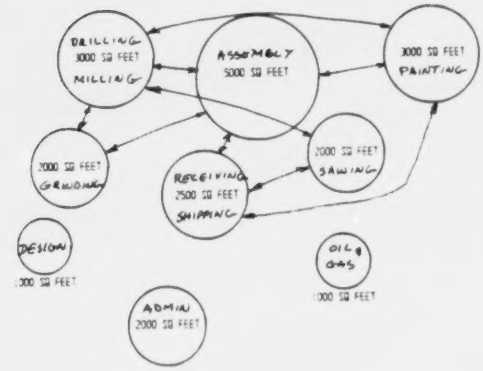
b. **Bubble diagram** — Used to establish relationships among spaces to designers

Example: A bubble diagram represents the area of the space and links are drawn to represent the strength of the relationships.

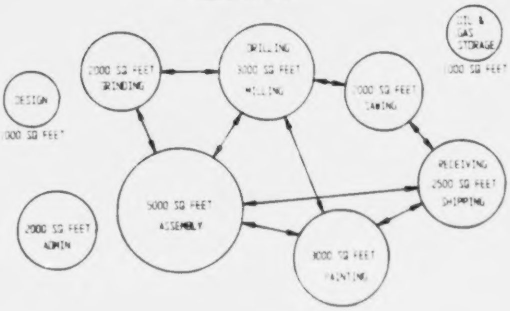
BUBBLE DIAGRAM CIRCLES
SCALE 1=.025


R 5 64
R 12 60
R 17 84
R 25 23
100 SQ FEET
500 SQ FEET
1000 SQ FEET
2000 SQ FEET
3000 SQ FEET
4000 SQ FEET
5000 SQ FEET
R 30 90
R 35 68
R 39 90
2500 SQ FEET
R 28.21
EXAMPLE IF AREA =2500 SQ FEET
RADIUS = √AREA/3 1416
RADIUS = √2500/3 1416 28 21

EXAMPLE BUBBLE DIAGRAM
SCALE 1=.025


DRILLING
3000 SQ FEET
MILLING
ASSEMBLY
5000 SQ FEET
3000 SQ FEET
PAINTING
2000 SQ FEET
GRINDING
RECEIVING
2500 SQ FEET
SHIPPING
2000 SQ FEET
SAWING
DESIGN
1000 SQ FEET
OIL & GAS
1000 SQ FEET
ADMIN
2000 SQ FEET

EXAMPLE BUBBLE DIAGRAM REORGANIZED
SCALE 1=.025


OIL & GAS STORAGE
1000 SQ FEET
DESIGN
1000 SQ FEET
2000 SQ FEET
GRINDING
DRILLING
3000 SQ FEET
MILLING
2000 SQ FEET
SAWING
RECEIVING
2500 SQ FEET
SHIPPING
5000 SQ FEET
ASSEMBLY
2000 SQ FEET
ADMIN
3000 SQ FEET
PAINTING

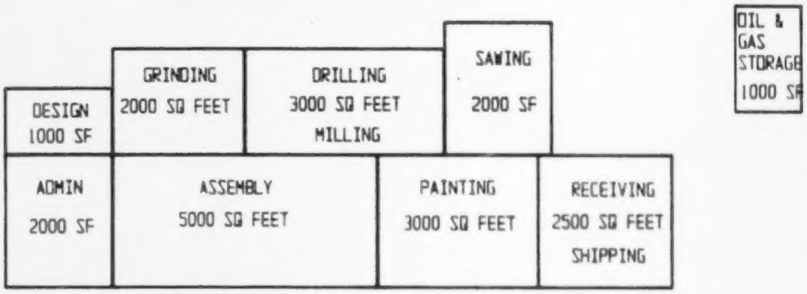
Information Sheet

c. **Block diagram** — A rough approximation of the physical size of each space with the correct relationship of spaces relative to each other

EXAMPLE BLOCK DIAGRAM STEP ONE

SCALE 1=.025

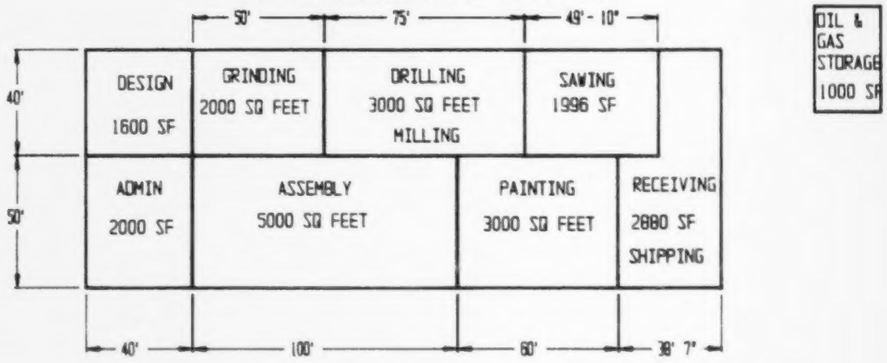
BUBBLES CHANGED TO RECTANGLES OF SAME AREA AND GROUPED TOGETHER ACCORDING TO BUBBLE DIAGRAM.


DESIGN
1000 SF
GRINDING
2000 SQ FEET
DRILLING
3000 SQ FEET
MILLING
SAWING
2000 SF
OIL &
GAS
STORAGE
1000 SF
ADMIN
2000 SF
ASSEMBLY
5000 SQ FEET
PAINTING
3000 SQ FEET
RECEIVING
2500 SQ FEET
SHIPPING

EXAMPLE BLOCK DIAGRAM STEP TWO

SCALE 1=.025

BLOCK DIAGRAM IN STEP ONE IS REVISED TO FIT A BUILDING PLAN.
NOTICE THE INCREASE AREA OF SOME SPACES


50'
75'
49'- 10"
OIL &
GAS
STORAGE
1000 SF
40'
DESIGN
1600 SF
GRINDING
2000 SQ FEET
DRILLING
3000 SQ FEET
MILLING
SAWING
1996 SF
50'
ADMIN
2000 SF
ASSEMBLY
5000 SQ FEET
PAINTING
3000 SQ FEET
RECEIVING
2880 SF
SHIPPING
40'
100'
60'
38' 7"

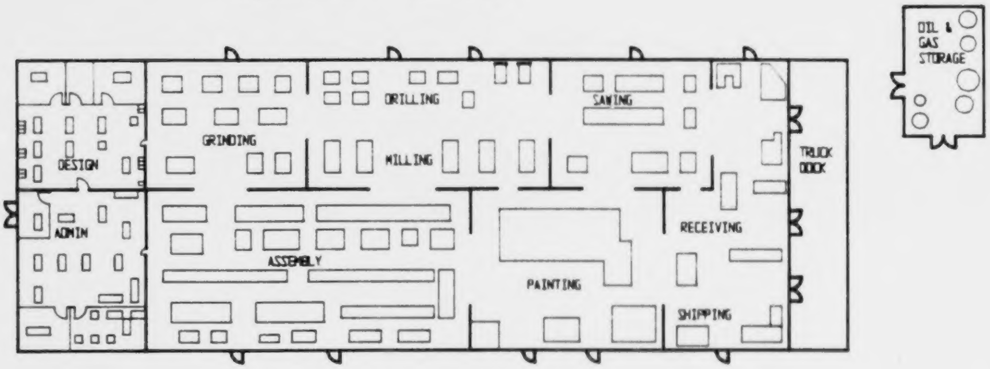
Information Sheet

d. **Detailed floor plan** — An accurate scale drawing showing the physical location of each piece of equipment

Example: Columns, walls, and aisles

EXAMPLE FACILITY LAYOUT

USING THE BLOCK LAYOUT AND DETAILS
OF EQUIPMENT AND FURNITURE THE FACILITIES
DESIGNER CREATES A FACILITY LAYOUT.


OIL & GAS STORAGE
DRILLING
SAWING
GRINDING
MILLING
DESIGN
TRUCK DOCK
ADMIN
RECEIVING
ASSEMBLY
PAINTING
SHIPPING

Facility Layout
Unit 13

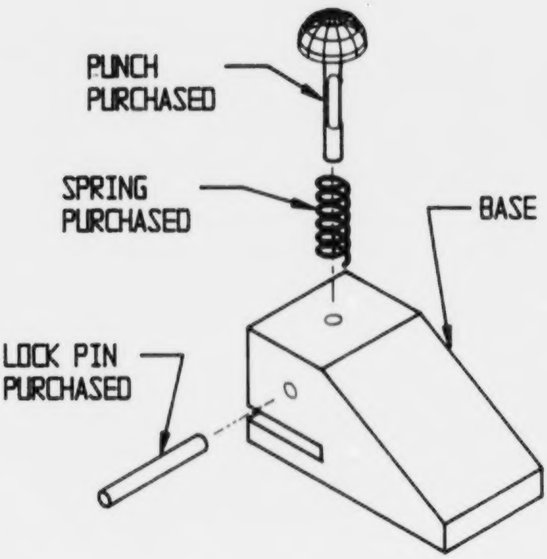
Assignment Sheet 1—Create a Process Flow Diagram

Name ____________________ Overall Rating __________

Evaluation criteria	Rating
Creates correct heading	______
Creates process flow diagram correctly	______
Creates proper summary	______

Directions: Create a Process Flow Diagram for the manufacture of a disk punch. Assume the disk punch is part# 48594. Use the Process Flow Chart on the following page to complete your project.

CAD Alert: Use a CAD system to create your process flow diagram.


PUNCH PURCHASED
SPRING PURCHASED
BASE
LOCK PIN PURCHASED

Assignment Sheet 1

1. Raw material in receiving (BAR 1″ × 1″ × 10′ 1020 steel)
2. To Power Hacksaw with reciprocating blade (20 Bars) 33 Ft.
3. Saw to length 2″
4. Check length
5. In boxes
6. To Milling machine #1 62 Ft.
7. Mill slot .125″
8. Check length
9. In boxes
10. To Milling #2 23 Ft.
11. Mill angle 30 degrees
12. In boxes
13. To vertical drill 20 Ft.
14. Drill two .125″ dia holes and countersink
15. In boxes
16. To grinder 45 Ft.
17. Grind all surfaces to specifications
18. In boxes
19. To assembly 45 Ft.
20. Assemble punch, spring, base, and lock pin
21. In shipping boxes
22. To shipping 127 Ft.
23. Storage waiting for order

Assignment Sheet 1

FLOW PROCESS CHART EXAMPLE

PART NAME:
PART NUMBER:
PROCESS DESCRIPTION:
CHARTED BY:
DATE:

PRESENT/NEW METHOD	FLOW	COMMENTS
	○ ⇨ □ D ▽	
	○ ⇨ □ D ▽	
	○ ⇨ □ D ▽	
	○ ⇨ □ D ▽	
	○ ⇨ □ D ▽	
	○ ⇨ □ D ▽	
	○ ⇨ □ D ▽	
	○ ⇨ □ D ▽	
	○ ⇨ □ D ▽	
	○ ⇨ □ D ▽	
	○ ⇨ □ D ▽	
	○ ⇨ □ D ▽	
	○ ⇨ □ D ▽	
	○ ⇨ □ D ▽	
	○ ⇨ □ D ▽	

SUMMARY	NUMBER
OPERATIONS	
TRANSPORTATION	
INSPECTIONS	
DELAYS	
STORAGES	
DISTANCE TRAVELED	

Facility Layout
Unit 13

Assignment Sheet 2—Create a Relationship Matrix

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
Creates correct names in spaces	_____
Creates correct relationships	_____

Directions: Create a Relationship Matrix using the information from Assignment Sheet 1 and the information that follows. As you complete your Relationship Matrix, keep in mind that the disk punch is only one of 15 other products produced by this company.

CAD Alert: Use a CAD system to create your matrix.

SPACES

Main office — receptionist, secretary, president, vice president, accountant, clerk, 6 people, 2,000 sq feet
Next to engineering office

Engineering office — one engineer, two CAD operators, one secretary, 4 people, 1,000 sq feet
Next to main office

Milling area — 4 milling machines with operators, 4 people, 3,000 sq feet
Next to drilling area, sawing area

Drilling area — 5 vertical drills, 3 people 2,500 sq feet
Next to milling area, sawing area, assembly area

Sawing area — 3 power hacksaws with reciprocating blade, 2 people, 1,000 sq feet
Next to milling area, sawing area, drilling area

Grinding area — 2 horizontal grinders, 1 person, 1,500 sq feet
Next to milling area, assembly area

Assembly area — 15 assembly areas, 32 people, 4,500 sq feet
Next to milling area, grinding area, painting, shipping

Assignment Sheet 2

Painting area — 2 painting lines, 4 people, 3,000 sq feet
    Next to assembly area, shipping area

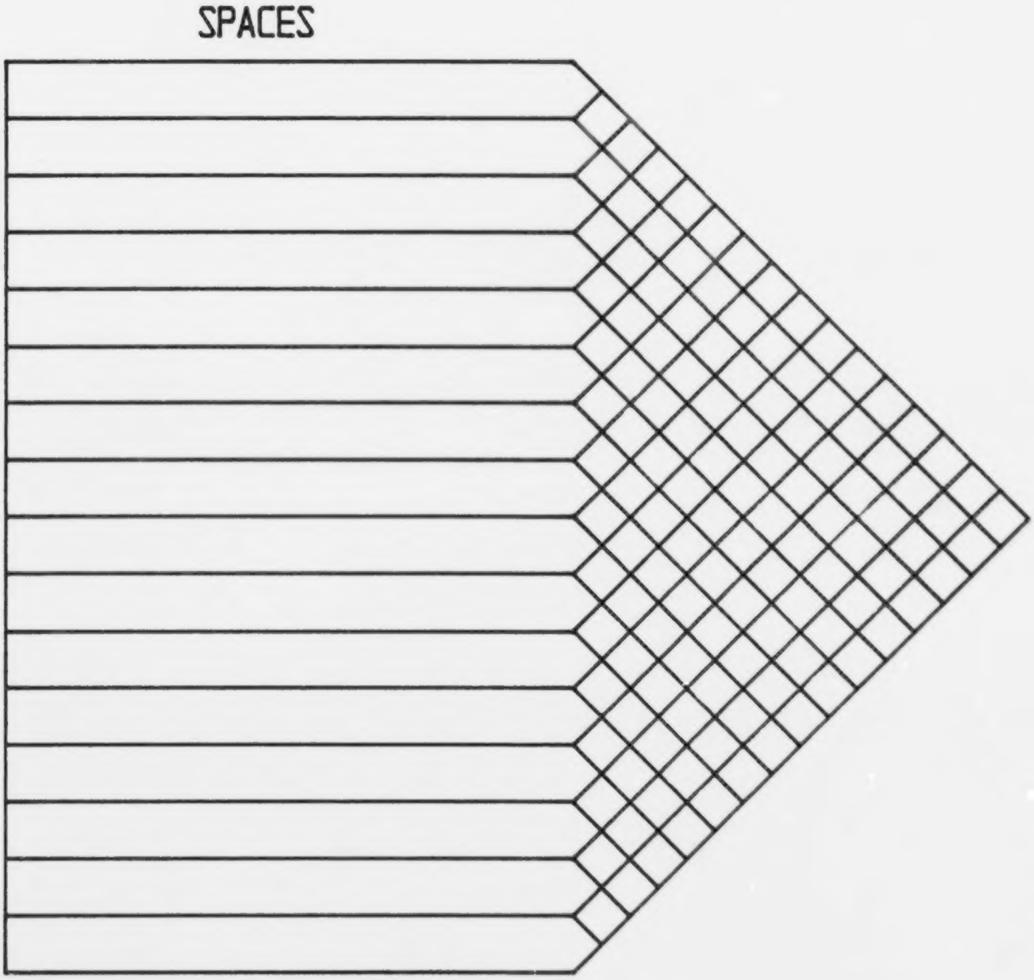
Storage area — 2 people, 4,000 sq feet
    Next to shipping, painting

Shipping — 3 people, 1,500 sq feet
    Same as receiving area, painting

Receiving — 2 people, 2,000 sq feet
    Same as shipping area, sawing area

Assignment Sheet 2

RELATIONSHIP MATRIX



1--SPACES MUST BE ADJACENT.
2--ADJACENCY PERFERRED, BUT NOT ABSOLUTELY NECESSARY.
3--PLACE THE SPACE ANYWHERE.
4--DISTANCE IS IMPORTANT.
5--SPACES SHOULD BE APART OR IN DIFFERENT BUILDINGS.

Facility Layout
Unit 13

Assignment Sheet 3—Create a Bubble Diagram

Name ______________________________ Overall Rating __________

Evaluation criteria	**Rating**
All bubbles drawn with correct diameters	______
All bubbles correctly connected with arrows	______

Directions: Create a bubble diagram using information from Assignment Sheets 1 and 2, or information provided by your instructor. Keep in mind that the disk punch is only one of 15 other products this company produces. Create circles for the bubbles by using the area formula for a circle. Create the arrows by using the relationship matrix, and the information that follows. Select an appropriate size sheet of vellum and scale to fit the problem. Since the first layout of bubbles and arrows may be a mess, create a second layout to clean up overlapping and crossing arrows. Relocate circles to shorten arrows and help show relationships of individual departments. Because several solutions may be correct, talk the project over with other students or have a discussion with your instructor.

> **CAD Alert:** Using CAD for your bubble diagram permits you to easily move the diagram circles around to form a good layout with few overlapping arrows.

SPACES

Main office — 2,000 sq feet
    Next to engineering office

Engineering office — 1,000 sq feet
    Next to main office

Milling area — 3,000 sq feet
    Next to drilling area and sawing area

Drilling area — 2,500 sq feet
    Next to milling area, sawing area, and assembly area

Sawing area — 1,000 sq feet
    Next to milling area, sawing area, and drilling area

Assignment Sheet 3

Grinding area — 1,500 sq feet
Next to milling area and assembly area

Assembly area — 4,500 sq feet
Next to milling area, grinding area, painting, and shipping

Painting area — 3,000 sq feet
Next to assembly area and shipping area

Storage area — 4,000 sq feet
Next to shipping and painting

Shipping — 1,500 sq feet
Same as receiving area, and next to painting

Receiving — 2,000 sq feet
Same as shipping area, and next to sawing area

Facility Layout
Unit 13

Assignment Sheet 4—Create a Block Diagram

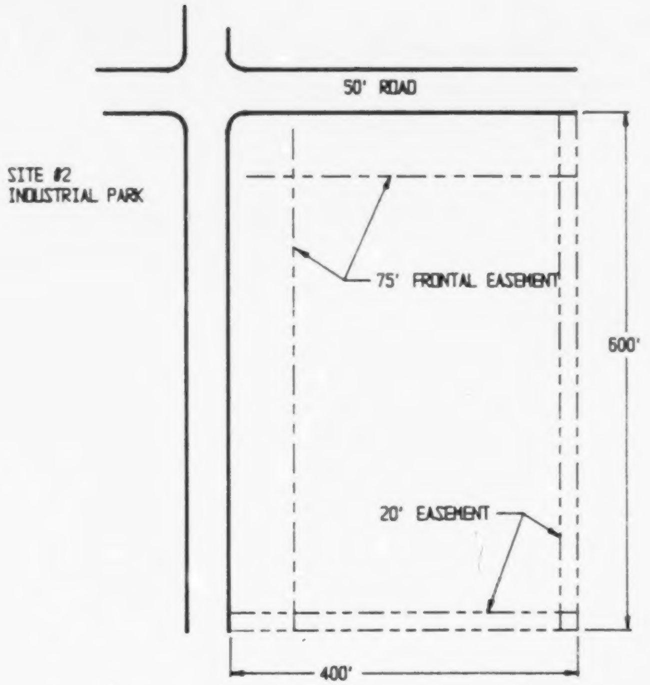
Name ______________________________ Overall Rating __________

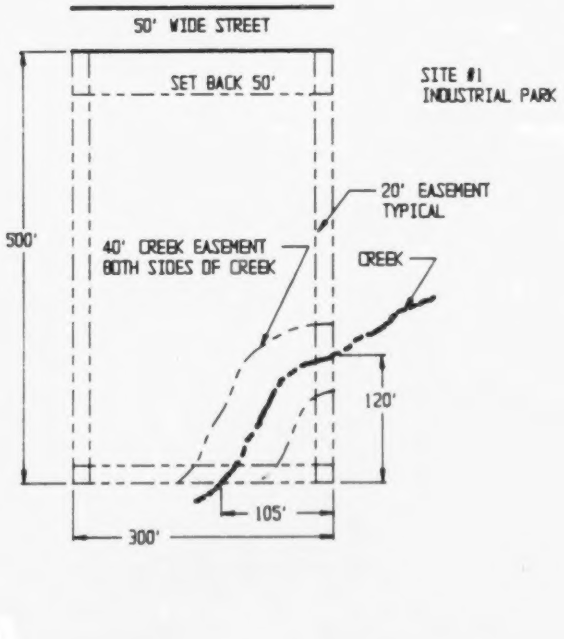
Evaluation criteria	**Rating**
Blocks reflect area ratios of bubble diagram	______
Blocks appropriately structured to show relationships	______
Areas with environmental considerations properly noted	______

Directions: Create a block diagram using information from Assignment Sheets 1, 2, and 3, or information provided by your instructor. Keep in mind that the disk punch is only one of 15 other products this company produces. Create rectangular blocks of the same area as the circles for the bubbles by using the area formula for a rectangle. By trial and error, select widths and heights so that when they are multiplied times each other the total will equal the area of the bubble. Using the arrows as guides, try to fit the areas together to form the structure of the building. Keep in mind the relationship matrix and areas with environmental considerations. Select an appropriate size sheet of vellum and scale to fit the problem. Since the first layout of the block diagrams may be a mess, create a second layout by cutting out block areas from paper stock and taping them together to form relationships. Adjustments in areas can be made to include reducing or increasing the size of areas by changing the lengths and widths of the areas. Several solutions may be correct, so discuss problems with your instructor or other students. Construct your final diagram only after proper planning. Select one of the two site plans that follow to see if your plan will fit either one of them. Decide what you would need to do to the site plan to improve the layout, or what you need to do to improve the block diagram.

CAD Alert: Using CAD for your diagram permits you to easily move the blocks around, put the site plan on a separate layer, or rotate and mirror the diagram.

Assignment Sheet 4


50' ROAD
SITE #2
INDUSTRIAL PARK
75' FRONTAL EASEMENT
600'
20' EASEMENT
400'


50' WIDE STREET
SET BACK 50'
SITE #1
INDUSTRIAL PARK
20' EASEMENT
TYPICAL
500'
40' CREEK EASEMENT
BOTH SIDES OF CREEK
CREEK
120'
105'
300'

Facility Layout
Unit 13

Assignment Sheet 5—Create a Facility Layout

Name ______________________ Overall Rating __________

Evaluation criteria	**Rating**
Layout reflects appropriate relationships	_____
Layout contains proper dimensioning and notes	_____
Layout presents proper safety and environmental information	_____

Directions: Create a facility layout using information from Assignment Sheets 1, 2, 3, or 4, or information supplied by your instructor. Using the block diagram as a guide, create a facility layout to include: door openings, aisles, offices, materials handling areas, machines and equipment. Each piece of equipment or machine can be cut out of cardboard and arranged in its appropriate area on the layout. An alternate method would be to draw each piece of equipment or machine using a CAD system, and then insert the equipment into the layout. Select an appropriate size sheet of vellum and scale to fit the problem. Construct your final facility layout to include dimensioning and notes. Be sure to use the equipment, machines, and standards included with this assignment. Since several different layouts could be effective, talk the project over with other students, or have a discussion with your instructor.

Special preparation required: Visit the machine shop at your school or at a local industry. Make notes about facility layout. Read equipment or machine literature to collect vital information, or discuss the project with your instructor. As a student, you're expected to conduct some research, or even write to companies for information. When you do visit a working facility, make an outline sketch of the equipment and machines. Dimension both the base and height of the machine spaces required, and the amount of clearance around the equipment for a safe working environment.

CAD Alert: Use CAD to create your layout so you can create and move equipment with ease, or put equipment and machines on separate layers. CAD affords the opportunity to test several options in a short period of time.

Note: Normally, an industrial engineer, plant engineer, or facilities planner would supply the drafter with all required information,and the drafter would produce the facilities layout. However, in small industries, the drafter, under the direction of an engineer sometimes does a lot of the planning and organizing of facilities layout.

Assignment Sheet 5

Equipment, machines, and other standards:

1. Desks 36″ × 72″, 30″ × 60″
2. Chairs 24″ × 24″
3. Designer CAD workstations 36″ × 60″ drawing table and 36″ × 60″ CAD table
4. File cabinets 15″ × 29″, Drawing files 48″ × 60″
5. Grinders 36″ × 52″
6. Drill press 36″ × 36″
7. Milling Machines Horizontal 72″ × 84″, vertical 60″ × 72″
8. Assembly tables 36″ × 72″
9. Paint booth 72″ × 120″, 72″ × 96″
10. Hacksaw machine 36″ × 72″
11. Door openings 36″ wide, 48″ wide, 60″ wide, and 72″ wide
12. Aisles Minimum 60″ wide shop area, 36″ wide office area

Note: You will find additional information necessary for the detail layout in company literature located in *The Thomas Register*.